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The Water-quality Analysis System with Multi-Dimensional Spaces for Interpreting Environmental Situations

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Abstract

Water-quality analysis plays an essential role for human societies and it is related not only for designing environmental systems but also for environmental management systems. There are several implementations in previous water-quality analysis research, which have been studied as the significant parts of the analysis results: (1) local situation water-quality analysis and assessment results, indicating which information is not provided to the public globally, (2) data collection from different areas, indicating which scholars use different criteria and frameworks, and (3) complicated analytical results for the public use. The implementations have been realized with the limitation in water quality analysis.

This dissertation presents an automatic system for water-quality analysis using several databases and different contexts in dynamic sub-space selection contexts. This system obtains information resources by transforming the sensor-value information to language information. In this dissertation, a river water quality analysis system is presented as an automatic human-interpreting system by integrating the special knowledge of environmental engineering and semantic computing, especially the water-quality semantic space. The dissertation presents a new approach for water-quality analysis based on using semantic computing. As the previously existing semantic computing method, the Mathematic Model of Meaning (MMM) has been proposed in the other study as a fundamental semantic model. This dissertation uses this MMM for applying it to river-water-quality interpretation and semantic space featuring (parameter-relatedness weighting method) in the diverse river-water-quality variability analysis. This new knowledge can be created as a database in the water-quality field at the professional knowledge database level. This study also introduces a sensing data-analysis tool as river Sensing Processing Actuation processes (rSPA) for analyzing the water-quality based on SPA processes, which can be used in critical contaminants points, classification and real-time notification. In addition, this study proposes several processes as tools for analyzing a single parameter case and multi-water parameters case, and for reporting the analytical results from the multidimensional semantic space by interpreting the water-quality situation with the multiple water-quality parameters

and the heavy metal evaluation index. These analytical results can be shared in societies and can be widely used in a water quality resource analysis and management.

This dissertation also describes the overall structure of the river water-quality analysis system. The contributions of the dissertation to research communities are (1) this system implementation for water-quality analysis of any rivers in the world, (2) integration of various professional knowledge resources from experts on water-quality analysis, and (3) memory recall of water-quality situation from the world. This study also relates to the water-quality analysis field in terms of (1) a world water-quality reporting system and notification system of water quality for multiple areas and timelines, (2) the extraction of water-quality features in different viewpoints in dynamic sub-space selection contexts, (3) a river-water-quality comparison on the global scale and broader water-quality analysis, (4) a professional knowledge level-database in water-quality analysis, and (5) the interpretation of water quality for society by transforming the sensor-value information to the language information as the understandable information to public users with wording. The important functions of the proposed system are the creation of the level-judgment function and semantic ordering, which can be used in river water-quality analysis for recognizing the water quality situation in the world-wide scale.

Keywords: Water-quality Analysis System, An automatically human-interpreting system, Database, Semantic computing, river Sensing Processing Actuation (rSPA), Multi-dimensional Subspace of Water-quality, river Heavy Metal Evaluation Index (rHMEI)

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Chapter 1

Introduction

Pollution of water resources with biological, chemical, and physical contaminants by anthropogenic activity is an important environmental issue all over the world [1]. Water resource systems mainly relate to natural water sources which are open to the atmosphere, such as rivers and reservoir water [1]. The importance of watersheds is the river, which conveys wastewater and runoff from municipal activities, industrial activity, and farm [2–4].

The rivers are essential water resources that construct the basis of life. The increasing human population, economic expansion, industrialization, urbanization, and energy over-consumption, are all significant factors causing environmental pollution. The classification of pollution in a water resource is shown in Figure 1.1. These activities can cause pollution in the water phase. Furthermore, difference pollutants such as physical, chemical, and heavy metal, are recalcitrant and hardly decompose in nature. They also accumulate and contaminate both the environment and human beings [5–7].

Bacterial contamination (Coliform Bacteria and Fecal Coliform Bacteria) can cause health issues, and can also cause a variety of nosocomial infections of the urinary tract, respiration tract, blood [7], food poisoning, gastroenteritis, and neonatal meningitis [8]. Environmental demands and hazards from physical pollutants such as conductivity, total solids, total dissolved solids [9], and turbidity can occur in the short term (at more than standard values) and the long term (with less than standard values) [10]. Chemical pollutants affect to the ecosystem in water. The related parameter, dissolved oxygen, at a low concentration will form hazard for aquatic life [10]. Also, the biological oxygen demand parameter at a high concentration will affect aquatic life and cause sewage and increase of nitrate-nitrogen concentration. In addition, the high concentration of nitrate-nitrogen cause methemoglobinemia or blue baby syndrome and eutrophication concentration [10].

Rivers are the main water resources for human life and form ecosystems in many areas such as agriculture, aquatic life, industry, and irrigation regions. River water quality is one of the most direct and significant factor concerning to the health of humans and ecosystems. A feasible method and reliable information of the water-quality database for the assessment and analysis system for water resources are necessary for sustainable resource management.

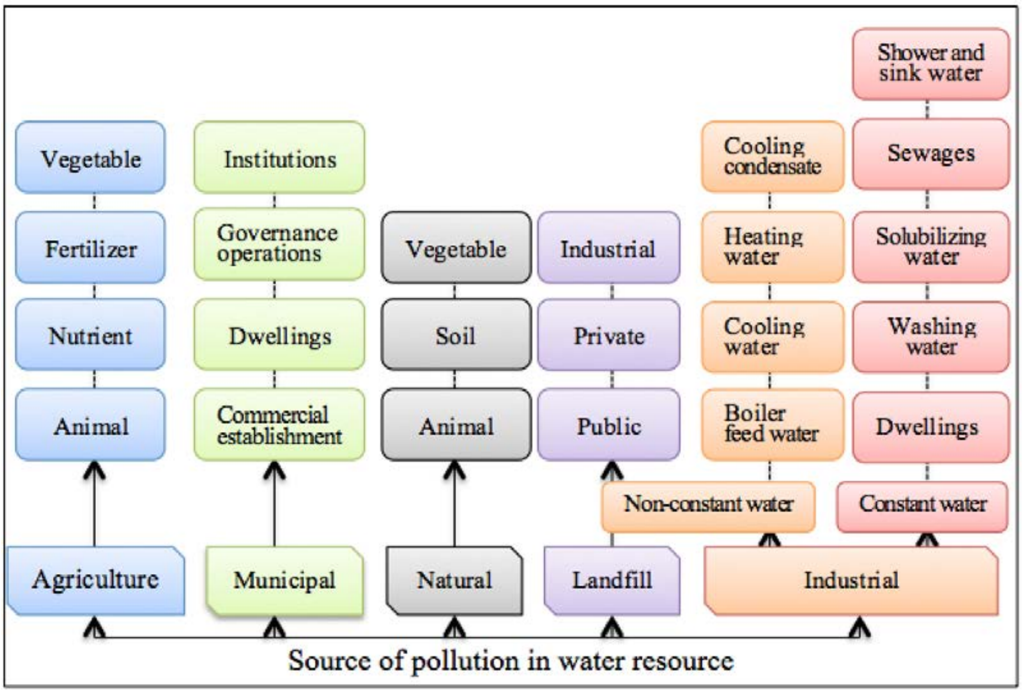


Fig. 1.1 The classification of pollution in water resource.

1.1 Water-quality Definitions

A summary of water-quality definitions in terms of biological, physical, and chemical characteristics from both the international institute and international guideline books are presented in Table 1.1

Table 1.1 The water-quality definition in terms of biological, physical and chemical characteristics.

Parameter	Symbol	Definition
Alkalinity	-	-The alkalinity refers to 3 types in aqueous systems which are Hydroxides (OH^-), Carbonates (CO_3^{2-}), and Bicarbonates (HCO^-). The concentration of this parameter is reported in mg/L as $CaCO_3$.
Ammonia	NH_3, NH_4^+	- Ammonia expresses 2 chemical species which are in equilibrium in water. Ammonia is toxic to aquatic organisms. It expresses and corresponds to a decrease of growth rates and damages gills, livers, and kidneys. The concentration of this parameter is reported in mg/L.
Biological Oxygen Demand	BOD	- The Biological Oxygen Demand is a measure of the total oxygen used by the indigenous microbial population (aquatic life) in water. The concentration of this parameter is reported in mg/L.
Conductivity	-	- The conductivity is related to the total dissolved solids and electrical conductivity. The concentration of this parameter is reported in μS. [11]
Coliform Bacterial	-	- A coliform bacteria is a Gram-negative bacteria which is rod shaped, non-spore forming, aerobic, and has facultative anaerobic growths. These bacteria live in the body of warm-blooded animals. This parameter is used to represent the pathogenic organisms of humans such as Klebsiella bacteria etc., The concentration of this parameter is reported in Most Probable Number (MPN/100 mL) or in Colony Forming Unit (CFU/100 mL).

Table 1.1 – The water-quality definition in terms of biological, physical, and chemical characteristics. (*Cont.*)

Parameter	Symbol	Definition
Fecal Coliform Bacterial	-	- A fecal coliform bacteria is a Gram-negative bacteria, which is rod shaped, non-spore forming, and has facultative anaerobic growths. These bacteria live in animal or/and human waste. This parameter is used to represent the pathogenic organisms of humans such as Escherichia coli bacteria and Enterococci bacteria etc., The concentration of this parameter is reported in Most Probable Number (MPN/100 mL) or in Colony Forming Unit (CFU/100 mL).
Dissolved Oxygen	DO	- The concentration of oxygen that is required by microorganisms, fish, and other aqueous life in aquatic systems. The concentration of this parameter is reported in mg/L.
Hardness	-	- The values of Hardness are representative of the total concentration of metal anions (X^{2-} form). Hardness is the main parameter for the potential precipitation of calcium carbonate into dregs in tubes, boilers, cooling towers, and results in a poor taste to the water. The concentration of this parameter is reported in mg/L as $CaCO_3$.
Nitrate-nitrogen, Nitrite-nitrogen	NO_3^--N, NO_2^--N	- The nitrate and nitrite anions are the result of the bacteriological oxidation of nitrogen in soil. The nitrate and nitrite anions are among the indicators for the degree of pollution in water with nitrate-content substances (high values for nitrate anions causes ”Algae Bloom Crisis” and ”Acid Precipitation”). The concentration of this parameter is reported in mg/L.
Potential of Hydrogen ion	pH	- The measurement of acidity and basicity in aqueous solutions is shown in theory, the pH in water should be between 0-14 and pure water should have pH = 7.0 [11]

Table 1.1 – The water-quality definition in terms of biological, physical, and chemical characteristics. (*Cont.*)

Parameter	Symbol	Definition
Phosphate-Phosphorus	PO_4^{3-}-P	- Phosphorus is an essential nutrient for aquatic species and aquatic vegetation. The effect of limiting phosphorus in the water body does not express quantities of aquatic life and aquatic vegetation. An increase of phosphorus in a water body generates algal bloom and affects on an aquatic species and vegetation, such as coral. The concentration of this parameter is reported in mg/L-P.
Total Dissolved Solid	TDS	- Total Dissolved Solids refers to solid compounds or articles in the solid phase dissolved in water such as inorganic acids and organic compounds. The concentration of this parameter is reported in mg/L.
Total Solid	TS	-Total Solids can refer to total solid compounds or particles in the solid phase in water after evaporation of the water and drying of the solid compounds or articles in the solid phase at 103 °C-105 °C. The concentration of this parameter is reported in mg/L.
Salinity	-	- Salinity is a measure of the concentration of total dissolved salts in the water body as ions form and the concentration of this parameter is reported in ppt. A high salinity affects the growth of aquatic life and aquatic vegetation by a decrease of the osmotic pressure, with effects on the water flow equilibrium of aquatic vegetation. The concentration of this parameter is reported in Part-Per-Trillion (PPT).
Suspended Solids	SS	- The Suspended Solids refers to solid compounds or particles in the solid phase are not dissolved in the water but are rather suspended. The concentration of this parameter is reported in mg/L.

Table 1.1 – The water-quality definition in terms of biological, physical, and chemical characteristics. (*Cont.*)

Parameter	Symbol	Definition
Turbidity	-	- The Turbidity can be caused by infection of the soil, sand, algae, plankton, diatom, and colloid. It is an efficiency indicator for water analysis in the environmental field which is measured by the light-transmitting properties of the water. The concentration of this parameter is reported in Nephelometric Turbidity Unit (NTU).
Temperature	-	- Temperature is a physical property in a water body. The temperature affects to metabolic rates and biological activity of aquatic life.

1.2 Objective

This dissertation focuses on (1) a new approach to a water-quality analysis method based on semantic computing with the Mathematic Model of Meaning (MMM) [12], which can be defined to deal with dynamically changing situations and to extract water-quality features for different user purposes. It is an automatic system and uses dynamic sub-space selection according to the context. (2) The use of a water-quality monitoring system by utilizing Sensing Processing and Actuation (SPA) processes [13] and developing the integration from a meta-level knowledge of the database system.

Our proposed method aims to establish a professional knowledge level database in the water-quality field, semantic space creation as a newly proposed dynamic dimension for river-water-quality interpretation, and a semantic space feature-relatedness weighting method for diverse river-water-quality variability.

The method for monitoring and realizing the SPA processes is analyzed, illustrating the critical contamination points in the classification by using single- and multi-water-quality parameters for public knowledge utilization. The method for creating a multidimensional semantic space for water-quality analysis is in the processing (P) of the river Sensing Processing and Actuation(rSPA) processes, which is realized to prepare the protection and treatment processes in several categories.

1.3 Problem

Currently, the immense issue of global environmental pollution relates to water quality, which is mainly caused by human activity in our daily lives. There are many implementations and tools that have been created for water-quality analysis and the explanation of the environmental change thereby caused.

Many of the research result in water management that have been developed and applied in practice for the early warning systems are based on Geographic Information System (GIS). The limitation of these systems is the analysis function of the warning, and technologies to obtain water-quality data. Those are not competently used and also not statistically significant to estimate systems [14, 15].For instance, the emergency warning system for the Chu river downstream basin by L. LI et al. [14] can only generate a real-time simulation for a contamination accident. This system only observes data and historical materials [14], it does not calibrate the fundamental parameters, and the accuracy of the scenario simulation system has not been validated. FDEWS 2.0: A Web-GIS-Based Early Warning System for Fish Disease via Water Quality Management by L. Nan et al. [15] has an effective warning potential for fish diseases and manages water quality in cases of ponds and low-cost water ecology systems. Apparently, the limitation of the system is that the factors selected by the controller are applicable only in Tianjin, China.

The most important issue in the water-quality situations is that local situation water-quality analysis and knowledge-based results are not provided globally. Because water-quality data are collected over different areas, and different criteria are used in different frameworks analyses, as shown in previous implementations, the overall meaning of the results are too complicated for public use.

The purpose of this study is to solve this limitation by explaining the results by using understandable wording by transforming sensor-value information to language information. The study also analyses the system of pollutants in preparation for the protecting and treatment processes in industrial manufacturing.

1.4 Research challenges and expected results

Research challenges

Currently, there are many research challenges taking place in water-quality areas. This research focuses on:

- Using understandable words for public utilization: how to capture the analyzed results in simple words?
- Actuation system: how to implement the reporting and notification as a flexible system in local and global areas?
- Integration of knowledge: how to integrate the knowledge bases of environmental engineering and semantic computing for a promising water-quality analysis system?
- Professional knowledge: how to acquire the analyzed results at a professional level?

Expected Results

- Database: the user can acquire the knowledge and essence by using the database system of water quality.
- Processes: the user can acquire the newly interpreted environmental situations.
- Function: the user can acquire the results and receive the notification of environmental situations.
- Feature word: the user can acquire the in-depth water-quality analysis at the level of professional knowledge by using simple scientific word interpretation.

1.5 Organization of this dissertation

This dissertation is divided into 9 chapters as follows.
Chapter 1: Introduction, this chapter gives the background information on water resources, the definition of water-quality parameters, objectives, problems and the current situation in the water-quality analysis field, research challenges, and expected results of this dissertation.
Chapter 2: Related work, this chapter introduces the literature review that presents the related work in the water-quality analysis field, semantic computing, and semantic computing in MMM.
Chapter 3: Proposed method, this chapter describes an automatic system for water-quality analysis with several databases and different contexts (categories) in

dynamic sub-space selection according to context, which is a new human interpretation of water-quality for society by transforming the sensor-value information to language information. This system consists of 5 modules:

- Water-quality analysis and visualization with the 5D World Map System, which are a new tools for water-quality evaluation with single parameter and multiple water-quality parameters for physical, chemical, and biological characteristics. The procedure of this module can be explained in 3 steps: (1) the application of the 5D World Map System to water-quality analysis, (2) the application of the water-quality index to water-quality analysis, and (3) the application of the metal index to water-quality analysis.

- River water-quality analysis method using rSPA processes, which is a tool to determine and classify single water-quality parameter in the river for critical contaminate detection, classification of multiple water-quality parameter values, and real-time notification. The procedure for this module can explained in 4 steps: (1) the procedure for water-quality parameter selection, (2) the procedure for designing standard threshold values for the database, (3) the procedure for designing standard classifications in the database, and (4) the procedure for the actuation and notification system based on trigger designing.

- Multidimensional water-quality and semantic space creation, which is a new analysis module for the environment in the water-quality area by integrated environmental analysis and semantic computing with a multidimensional concept for multiple water-quality parameters. The procedure for this module is described in 2 steps: (1) the procedure for pollutant-environmental variables and utilizing water design, (2) the procedure for multidimensional space creation.

- A river heavy metal evaluation index (rHMEI), which is a method for classification and interpretation of water-quality parameters by using a multidimensional concept with multiple heavy metal parameters based on the SPA concept. The procedure for this module can be explained in 2 steps: (1) procedure for index creation (rHMEI) by using a multidimensional concept with multiple heavy metal parameters, and (2) procedure to analyze the data by using an index in multidimensional space.

- Semantic-ordering function, which is a function for analyzing and evaluating the spatial-dynamic environmental change in multiple contexts by creating mathematical functions for multiple water-quality parameters. The procedure for this module can be described in 4 practical steps: (1) the procedure for raw data vector designing, (2) the procedure for establishing the professional knowledge level database in water-quality analysis, (3) the procedure for semantic space creation: a proposed dynamic dimension for river-water-quality interpretation, and (4) the procedure for a semantic space parameter-relatedness weighting method of diverse river-water-quality variability.

Chapter 4: Implementation, this chapter defines the water-quality analysis system. The main feature of this implementation is to illustrate the meta-level knowledge in the database system for water-quality analysis and to extract the essential base for human-language interpretation. This chapter consists of 2 parts:

- System design and database architecture.
- Data structure, which are observation data and open data based on the data structure for the 5D World Map System and semantic space.

Chapter 5: Data preparation, this chapter describes the study area and data collection.
Chapter 6: Analysis of result, this chapter presents the implementation results of each procedure.
Chapter 7: Evaluation, this chapter describes the performance of the method and implementation results with accuracy evaluation and the additional part of the mechanism to reflect specialists' knowledge
Chapter 8: Future application, this chapter describes the possibility of future work/application in the water-quality analysis field and other environmental fields.
Chapter 9: Summary, this chapter summarizes this dissertation with concluding remarks. Those include remarks concerning: (1) how this dissertation addresses the significant limitations that have not been solved by previous research; (2) the contribution in terms of research areas.
Appendix A: The strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis, this chapter presents the example of each context for establishing the new knowledge representation of the professional's knowledge in water-quality analysis.
Appendix B: The Appendix presents the results of the mechanism to reflect specialists' knowledge. This section used Water-quality Questionnaire and Feedback for the specialist of water-quality analysis field as the tools for reflecting the specialist's knowledge to the system. This questionnaire is consists of 2 parts:

- Feedback of water-quality criteria and classification class in each context
- Feedback of suggestion for improvement system

Appendix C: Research Publication, this chapter presents the research presentation and journal publications

Chapter 2

Related Work

Water resources are important for human life and used for consumption. In addition, the world population has been increasing sharply and the technological development in industrial areas has expanded widely; this has become a big problem. Agricultural activities and industrial manufacturers have greatly affected water resources in terms both of quality and quantity. The effect on water resources has led to several problems such as flooding, water shortages, pollutant contamination, and accumulation of waste water. These problems have resulted in a diminished quality of life.

2.1 Water-quality Analysis

Water quality analysis is one of the most important aspects of designing environmental systems. Many implementations and tools have been developed for water quality analysis for explanation of the environmental changes [16].

One of the tools to analyze overall the characteristic of water quality in a simple way is the water-quality index [17]. Water-quality indexes (WQIs) were first formulated and used by Horton [18]. Horton (1965) proposed an evaluation of the drinking water supply [18]. Secondly, Brown et al. (1970) proposed an extension to the water-quality index with standard measures for comparison of the water quality from different water resources [19].

- Bordalo et al. (2000) re-conceptualized and named the Scottish WQI in particular for use in tropical environments as an application of the water-quality index. The index in this research provided a simple method for expressing the results of several parameters in order to assess the water quality in Bangpakong River (Thailand) from June 1998 through May 1999 at 11 sites along a 227 km stretch during the wet and dry seasons. As a result, using the Scottish WQI it was possible to classify the water quality both spatially and temporally under the watershed by means of uniform, objective criteria [20].

- Fabiano et al. (2007) presented a water-quality index (WQI) to evaluate the water quality in the Medio Paranapanema watershed in Sao Paulo State, Brazil between May 2003 and May 2005. The parameters of turbidity, total phosphorus, and dissolved oxygen were used for the proposed index and normalized on a scale from 0 to 100. Then, the index scale was translated into a water-quality statement as shown by the scales (excellent, good, regular, fair, and poor). As a result, this index can easily infer watershed degradation [21].

- Ma et al. (2014) used artificial neural network modeling of the water-quality analysis from Litopenaeus vannamei shrimp tanks. The researcher used a backpropagation neural network (BP-NN) model for predicting the water quality in the Litopenaeus vannamei shrimp tanks. According to their implementation, 9 parameters were used with 4 different shrimp tanks and the authors collected the water-quality data over 120 days (July 1 to October 28, 2008). As a consequence, they found good agreement in water quality value between the implementation value and the BP-NN model. The model efficiently predicted the water quality in the shrimp tanks, which was evaluated by the correlation coefficients scale in a set of Training, Testing, and Training + Testing data (the computed results and experimental values are 0.990, 0.979, and 0.992 respectively) [22].

- Nazeer et al. (2014) studied risk assessment and water-quality characterization using the water-quality index at the Soan River, Pakistan. The study was based on the trace metals distribution both dissolved and in sediments then determined the water quality by using water index. Moreover, they found that the nutrient loading in the water samples was relatively high during the pre-monsoon and post-monsoon seasons. The pre-monsoon season showed the best water quality determined by using the water quality index [23].

- Garaba et al. (2015) proposed an assessment of water-quality monitoring tools in the Estuarine System. The researcher monitored and analyzed the bio-geophysical and optical water quality by using different ocean color remote sensing (OCRS). They used observations in water quality parameters from three submerged platforms where data were collected from the water surface and satellite information. It could provide comparable measurements in some form with an accuracy precision test. The most striking features were the high improvement in spatial resolution OCRS approaches and also predictive regression models. This marked progress of remote sensing for estuarine waters for continuous water-quality observation [24].

2.2 Semantic Computing

Semantic computing is a technology for composing information content based on meaning, numerics, symbols, notations, concepts, functions, and vocabulary, which are included in the software. Information content on semantic creation is shared by the specialists in various fields via a computer for the design and operation of the information system. Semantic computing is an important technology for semantic analysis in various fields [25–27].

2.3 Semantic Computing in the Mathematic Model of Meaning (MMM)

Semantic computing in MMM is computing based on semantics in terms of context meaning. Semantic computing in MMM is a useful technology in multidisciplinary research to compose the information context and to share between users. It is a designed and operated information system. The semantic analysis is related to environmental field study [12, 28].

- Kiyoki et al. (1994) proposed a meta-database system, which realizes the semantic associative search for images by giving keywords and representing the user's impressions and the image contents. The key in this model is the semantic associative search, which is performed in the orthogonal semantic space. In lexical terms, semantics are created for dynamically computing semantic equivalence or similarity between the meta-data items of the images and keywords. As a result, a tangible system is formed for use as a basic computational system for extracting appropriate images [12].
- Kiyoki and Ishihara (2003) used a semantic search space integration method for a heterogeneous data environment. From the heterogeneous databases, the researcher realized among various semantic search spaces for meta-level knowledge acquisition. These authors integrated common concepts between different databases in a heterogeneous field. As a consequence,

they generated an integrated semantic space in the system which has the ability to analyze field independence [28].

- Sasaki et al. (2010) illustrated the 4D World Map System by using semantic and spatio-temporal analyzers. The researchers designed and implemented the 4D World Map System. A knowledge representation system and the visualization of the analyzed results as a 4D dynamic historical atlas. As a result, the system gives high visibility of semantic correlations between document data in time series [27].

- Kiyoki and Chen (2014) presented a contextual and differential computing approach for the multi-dimensional world map with context-specific spatial-temporal and semantic axes. The researchers created a new method to discover the nature of global problems by utilizing differential computing of data in the Multi-Dimensional World Map. To summarize, they highlighted factors, using the Multi-Dimensional World Map, in a manner which makes observing and analyzing the nature of environment changes [13].

- Kiyoki et al. (2016) discussed a new semantic computing method with multi-spectrum images for analyzing and interpreting environmental phenomena in the physical world. Researchers illustrated a semantic associative search in the multiple-color spectrum based on a dimensional orthogonal semantic space and semantic projection functions. This method created an interactive and real-time cultural exchange in academic research on world issues [29].

Chapter 3

Proposed Method

This dissertation proposes a river water-quality analysis system as an automatic human-interpreting system by the integration of special knowledge in the areas of environmental engineering and semantic computing. It is proposed as a new flexible tool to employ river Sensing Processing Actuation (rSPA) processes for analyzing the water-quality field based on SPA processes [13]. The automatic human-interpreting system gives a multi-dimensional semantic space for multiple water-quality parameters and heavy metal index. Meanwhile, rSPA shows new single and multiple water-parameters analysis and notification processes. These results produce a method for the access to scientific information and interpretation in water resource quality for society.

The advance of methodology for analyzing sensing data is in the integrated physical processes and computing based on the framework of Sensing Processing Actuation of a Cyber Physical System [30, 31], which is a potentially strong method in the 21st century.

The "Sensing Processing Actuation" (SPA) process in the database is an effective concept for supporting the definition of automatically performing initial actions that present real-time environmental events [13]. In rSPA processes, the sensing (S) is a sensing phase from water sensing equipment to produce raw data of the water-quality condition by inputting data to the system. The processing (P) is the phase for the analytical process with logic tests, knowledge databases, and the evaluation that will lead to the next action. The actuation (A) is an output and implementation action phase to create and deliver notifications and warnings, to suggest an action and update the current situation with results sent to the user.

Semantic computing is a combination of elements from semantic analysis, natural language processing, data mining, and related fields.

Semantic computing in MMM is a model for retrieval of information and knowledge in a context-dependent manner by semantic computations. MMM is used to find differences where similar meanings exist or to recognize the different meanings of a data item. The original idea of semantic computing in MMM [12] is outlined by the followings:

- Dimensional space creation
- Data mapping to the semantic space
- Subspace-selection according to context
- Matrix-based calculation for ranking, clustering, and classification with semantic context in an independent way

The limitation of the water-quality analysis field is undertaking analysis in various contexts where a dynamic situation exists. This research proposes new dynamic dimensions for river water-quality interpretation and a semantic space parameter relatedness weighting method for diverse river water qualities. This new approach to water-quality analysis is based on semantic computing in MMM. It is addressed via 3 cores problems in the water-quality analysis field as follows:

- Establishing the professional level knowledge databases in water-quality analysis as a new means of knowledge representation for local and international specialists, and for organizational knowledge in water-quality data interpretation.
- Understanding the meaning of simple computational content in context and translating this from sensor-value information to language information.
- Mapping water-quality data and creating contexts for the purposes of data meaning.

At present, pollution increases in the water resources that have effects on human health and environmental issues in world society. The previous implementation works and tools are created or developed for the analysis of water quality, such as an environmental index. The limitations of the analytical results are usually complicated for the public to understand, and there are also limitations relating to the processing of a specific target user and parameter. These limitations are disadvantaged by decreasing accuracy of analysis results. The processes to analyze water quality with expert knowledge in water resources will be important in this situation for realizing the notification and warning systems.

3.1 Water-quality Analysis and Visualization with 5D World Map System

In this subsection, this research applies the 5D World Map System (5DWM), which is used for the database system and water-quality evaluation with multi-parameters in terms of physical, chemical, and biological characteristics of water resource analysis by using the Water Quality Index (WQI) and Metal Index (MI). Water-quality data are visualized and analyzed in each spot and wide scale. The concept of the 5D World Map System is shown in Figure 3.1.

Application of 5D World Map System on Water-quality Analysis

The 5D World Map System is used for analyzing and visualizing river-water quality data, which are analyzed on spots along the river and time series. The procedure of the process is (1) visualization by using the 5D World Map System, and (2) analysis by using the Water Quality Index and Metal Index. In this part, the research focuses on water quality by evaluating the Water Quality Index and Metal Index in every spot. The Water Quality Index is a mathematical tool, which transforms large quantities of water-quality data into a single number for determination of the water quality [20–23] and the Metal Index (MI) is an indicator for determination of the level of metal concentration in the water bodies [21].

3.1.1 Water-quality visualized by using 5D World Map System

The 5D World Map System is a new tool for computing correlations in 5 dimensions, of which there are 3 dimensions for the 3 geographical axes (X, Y, Z), 1 dimension for the time axis, and 1 dimension for multiple semantic computing to evaluate the environmental situation.

This research creates the water-quality meta-data level on a 5D World Map System to evaluate water-quality pollutants in wide areas with several views to illustrate the sharing and visualizing situation from global viewpoints. Also, it provides the broader water-quality analysis in many spots along the rivers and compares river-water-quality on the global scale for water-quality analysis.

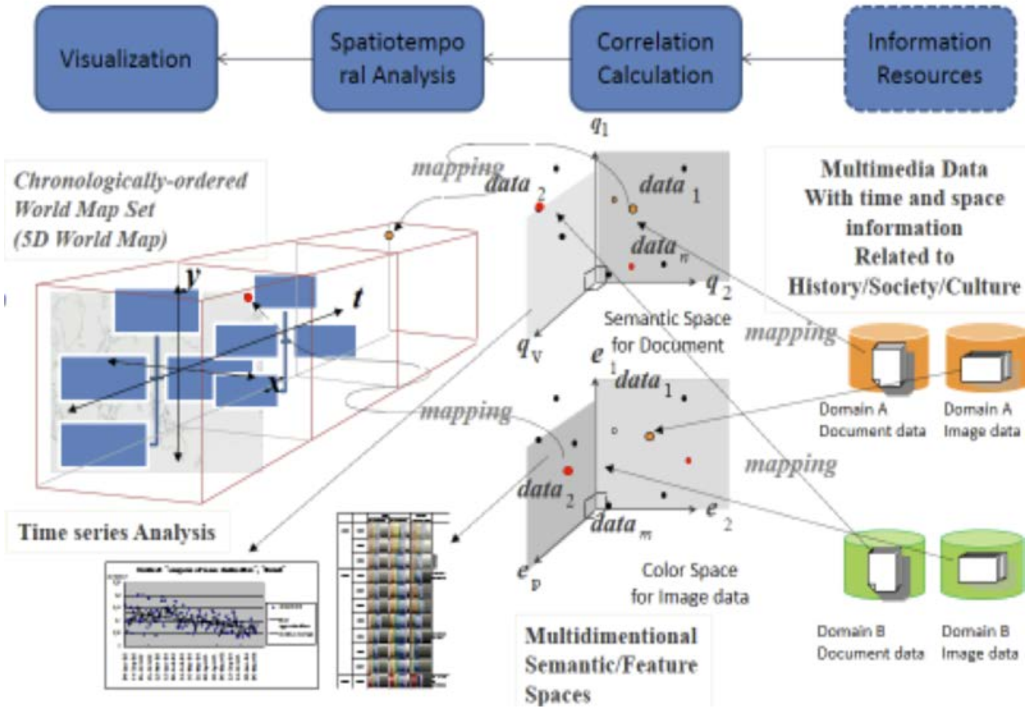


Fig. 3.1 The concept of the 5D World Map System [13, 27].

3.1.2 Water-quality visualized by using Water Quality Index

The Water Quality Index (WQI) is used to transform large quantities of water-quality data into a single number for the water-quality determination [21], [32]

Application of WQI on Water-quality Analysis

We applied the water-quality index (WQI) to analyze the river-water-quality. We aggregated the significant parameters into one factor. The formula for calculation is Eq. 3.1

When
Q_i is a sub quality index of the i^{th} parameter,
W_i is a weight unit of each parameter,
n is a number of parameters
The WQI is represented as

$$WQI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum_{i=1}^{n} W_i} \tag{3.1}$$

When
V_i is the value of measure of the i^{th} parameter,

S_i is standard of the i^{th} parameter, the standard concentration of each parameter according the international standard of water quality [7], [9] [33–35].

V_0 is an ideal value of the i^{th} parameter in distilled waters and V_0 = 0 except pH = 7.0 and DO = 14.6 mg/L [18], [35].

Q_i is calculated as

$$Q_i = \frac{V_i - V_0}{(S_i - V_0)} \tag{3.2}$$

When

K is a constant of weights for various water qualities and is represented as

$$K = \frac{1}{1/S_i} \tag{3.3}$$

the weight unit of each parameter W_i is

$$W_i = \frac{K}{S_i} \tag{3.4}$$

The WQI scores are classified into 5 classes of the water quality; excellent, good, poor, very poor and unfit [18].

Table 3.1 The classification of WQI.

Grading	Value	Rating of water-quality
A	(0 – 20)	Excellent
B	[20 – 40)	Good
C	[40 – 60)	Poor
D	[60 – 80)	Very poor
E	[80 – 100)	Unfit

3.1.3 Water-quality visualized by using Metal Index

The Metal Index (MI) is an indicator for determining the metal concentration in a river. The threshold for the warning is MI > 1.

Application of MI on Water-quality Analysis

This subsection applies the metal index (MI) to river-water-quality analysis. We aggregated the significant parameters into one factor. The calculation formula is Eq. 3.5

When

C_i is concentration of the i^{th} metal parameter,

MAC_i is maximum allowable concentration of i^{th} metal parameter according the standard of water quality for a water body [9] [36, 37], MI is calculated as

$$MI = \sum_{i=1}^{n} \frac{C_i}{MAC_i} \tag{3.5}$$

3.2 Water-quality Analysis by rSPA Processes

In this subsection, the study proposed a river Sensing Processing Actuation process (rSPA) for determination and classification of multiple water parameters in water resources. This water quality analysis method was conducted in Bangkok (Thailand). The rSPA process is a tool to detect and classify water-quality data with a simple framework. The results are explained by visualization, especially for public consideration and for an effective process for a warning system in the river-water quality analysis. The water quality analysis system gives notifications and warnings. The procedures of the process are;

- Step 1: To select the water parameter. The parameters of the water resource in this study are the conductivity, dissolved oxygen (DO), salinity, total dissolved solid, and turbidity.
- Step 2: To design the database for the standard threshold value. This database refers to the standard threshold values from the literature review and international organizations [33], [38]. The logic test and knowledge databases are processed by using PostgreSQL. The database of standard threshold values for multiple parameters is shown in Table 3.2 and the process for analyzing is shown in Algorithm 1.
- Step 3: To design the database in classification. In this database design, we refer to the effect range from the literature review and international organizations [32], [37], [39]. The logic test and knowledge databases are processed by using PostgreSQL. The database of the classification of multiple parameters is shown in Table 3.3 and the process for analyzing is shown in Algorithm 2.
- Step 4: To design the actuation and notification or warning system based on a trigger.

Table 3.2 The standard threshold value of the parameter.

Turbidity	Conductivity	Salinity	Dissolved Oxygen	Total dissolved Solid	Keyword
$\geq$ 20.00	$\geq$ 2000.00	$\geq$ 7.00	<4.80	$\geq$ 3000.00	Threshold warning
< 20.00	< 2000.00	< 7.00	$\geq$ 4.80	< 3000.00	Complete safe

Algorithm 1: Interpreting standard threshold value of parameter

Input: Feature type (v), feature value (val) is a real number
Output: Feature symbols of (v)

[Initalize semantic matrix]; dictionary ["DO"] = {Complete safe: ≥4.80, Threshold warning: 0.00-4.80}; dictionary ["Conductivity"] = {Complete safe: 0.00-2000.00, Threshold warning: ≤2000.00}; dictionary ["Salinity"] = {Complete safe: 0.00-7.00, Threshold warning: ≤7.00}
dictionary ["Total Dissolved Solid"] = {Complete safe: 0.00-3000.00, Threshold warning: ≤3000.00}; dictionary ["Turbidity"] = {Complete safe: 0.00-20.00, Threshold warning: ≤20.00}
Get feature dictionary with respect to feature type v using the parameter classification table;
For each item (keyword, value_range) in the feature dictionary;

Fig. 3.2 Algorithm 1: Interpreting standard threshold value of parameter.

Table 3.3 The classification of parameter.

Type/class	Conductivity	Dissolved oxygen	Total dissolved solid	Turbidity
Completely safe	<250.0	<6.5	<300.0	<20.0
Low effect	250.0–750.0	5.0–6.5	300.0–600.0	20.0–30.0
Intermediate effect	750.0–2000.0	3.0–5.0	6000–900.0	30.0 -40.0
High effect	2000.0- 3000.0	1.0–3.0	900.0–1200.0	40.0–50.0
Very high effect	≤3000.0	≤1.0	≤1200.0	≤50.0

Algorithm 2: Interpreting semantic meaning of a single feature

Input: Feature type (v), feature value (val) is a real number
Output: Semantic symbols of val

[Initalize semantic matrix]; dictionary ["DO"] = {Complete safe: 6.50-10.00, Very high effect: 0.00-0.99}; Low effect: 5.00-6.49, Intermediate effect: 3.00-4.99, High effect: 1.00-2.99, dictionary ["Conductivity"] = {Complete safe: 0.00-249.99, Low effect: 250.00-749.99, Intermediate effect: 750.00-1999.99, High effect: 2000.00-2999.99, Very high effect: 3000.00-10000.00}; dictionary ["Total Dissolved Solid"] ={Complete safe: 0.00-249.99, Low effect: 250.00-749.99, Intermediate effect: 750.00-1999.99, High effect: 2000.00-2999.99, Very high effect: 3000.0-10000.00};
dictionary ["Turbidity"] = {Complete safe: 0.00-19.99, Low effect: 20.00 29.99,Intermediate effect: 30.00-39.99, High effect: 40.00-49.99, Very high effect: 50.00-100.00};
Get feature dictionary with respect to feature type v using the parameter classification table;
For each item (keyword, value_range) in the feature dictionary;

Fig. 3.3 Algorithm 2: Interpreting classification of parameter.

3.3 A Multi-dimensional of water-quality and semantic space creation

In this subsection, the study proposed a new analysis system with semantic computing for environments in water-quality areas by integrating the fundamental important parameters for water quality. The multi-water-parameter analysis in a multi-dimensional space is important for current water-quality research issues, which are based on the values and meanings of each parameter for obtaining interpretations in the categories of agriculture, aquatic life, fish, drinking, industry, and irrigation. The multi-dimensional semantic space is significantly utilized for various interpretations related to the water quality.

The procedures are as follows; monitoring, evaluating the water quality of rivers for the public, and developing the meta-level knowledge in the system base for creating the multi-dimensional semantic space.

3.3.1 The procedure for pollutant-environmental variable and utilized water design

This work studies the pollutant-environment variables, public information, scientific research, the effect in terms of pollutant-environment, the water utilization, the semantic computing concept for dealing with the multiple water parameters. These can be analyzed from numeric to semantic wording. The designing of the relations between parameters in the semantic space is shown in Figure 3.4

3.3.2 The procedure for multi-dimensional space creation

In the second procedure of this subsection, the study applies semantic computing as a tool for water-quality data analysis. Especially, the actuation is semantic words for use in the system. The system process is shown in Figure 3.5 and the database of the target categories was created as follows:

- Step 1: The target context creation by multiple water parameters, effect words, and the chronic suddenly toxic class in the database.
- Step 2: The process selects the river water-quality parameters that relate to the target context (selected by the user) and creates the multi-dimensional semantic space.
- Step 3: This process of mapping input data into the multi-dimensional semantic space.

	Conductivity	Dissolved Oxygen	pH	Salinity	Total Dissolved Solid	Turbidity
C_1-Agriculture	1	0	1	1	1	0
C_2-Aquatic life	0	1	0	0	0	0
C_3-Drinking	0	0	1	0	1	1
C_4-Fish	0	0	1	0	0	0
C_5-Industry	1	0	1	0	1	0
C_6-Irrigation	1	0	0	1	1	0

Fig. 3.4 The relation of the parameters that effect to target group.

- Step 4: This process executes feature word processing by selecting the candidate's important word in the parameter ranges in the water quality fields.

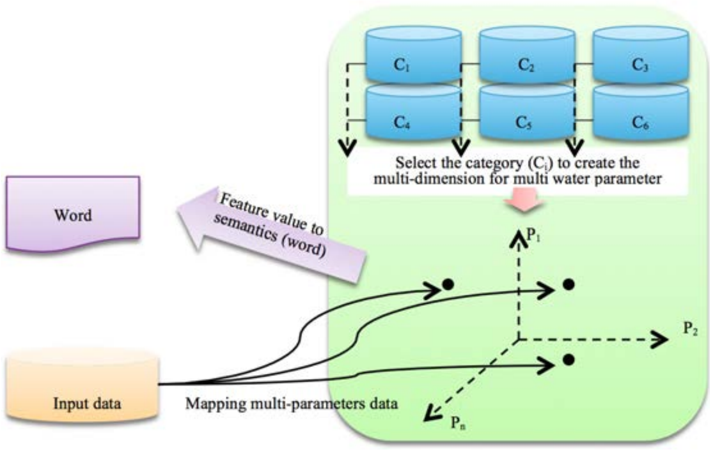


Fig. 3.5 The system processes of multi-dimensional space creation.

The process for analyzing of a multi-dimensional of water-quality is shown in Algorithm 3.

Algorithm 3: Interpreting semantic meaning of a multiple features

Input: Feature type (v), feature value (val) is a real number
Output: Semantic symbols of val

1 [Initalize semantic matrix]; dictionary ["Agriculture"] ← {cond, tds, sal}= {Excellent for agriculture: 0.0-249.0, 0.0–149.0, 0.0–0.14}, {Hazard for sensitive crop: 250.00-749.00, 150.00-499.00, 0.15-0.46}, {Hazard for low tolerance crop: 750.00-2249.00, 500.00-1499.00, 0.50-1.49}, {Hazard for high tolerance crop: 2250.00-4999.00, 1500.00-3199.00, 1.50-2.90}, {Satisfactory for livestock and poultry: 5000.00-7499.00, 3200.00-5199.00, 3.00-4.90}, {Hazard for poultry: 8000.00-19999.00, 5120.00-7039.00, 5.00-6.90}, {Unfit for agriculture: 20000.00-159999.00, 7040.00-10239.00, 7.00-9.99}, {Suddenly toxic for agriculture: 160000.00-1000000.00, 10240.00-20000.00, 10.00-100.00};

2 dictionary ["Aquatic life"] ←{DO}= {All aquatic life extinction: 0.00-2.99}, {Hazard for aquatic life: 3.00-4.99}, {Supports spawning: 5.00-5.99}, {Support growth and activity for aquatic life: 6.00-6.99}, {Abundant aquatic life: 7.00-10.00}; 3dictionary ["Drinking"] = ← {tds, turb}= {Optimum for drinking: 0.00-199.00, 0.00-1.99}, {Hazard for drinking: 200.0-599.00, 2.00-4.99}, {Hazard for drinking: 200.00-599.00, 2.00-4.99}, {Unfit and toxic for drinking: 600.00-1000.00, 5.00-10.00}, Unfit and toxic for drinking: 600.00-1000.00, 5.00-10.00}; 4dictionary ["Fish"] = ← {pH}= {All fish extinction: 0.00-3.99}, {All fish extinction: 10.50-14.00}, {Hazard for fish and salmon dying: 4.00-4.99}, {Hazard for fish and salmon dying: 8.20-10.49}, {Bacteria and plankton begin disappear: 5.00-5.99}, {Optimum for fish and shrimp: 6.00-6.49}, {Abundant for fish: 6.50-8.14}; 5dictionary ["Industrial"] = ← {cond, tds} = {Optimum for industrial processes: 0.00-2.99, 0.00-199.00}, {Slightly corrosive scaling and fouling: 30.00-49.00, 200.00-349.00}, {Slightly corrosive scaling and fouling: 30.00-49.00, 200.00-349.00}, {Moderate corrosive scaling and fouling: 50.00-199.00, 350.00-799.00}, {Moderate corrosive scaling and fouling: 50.00-199.00, 350.00-799.00}, {Highly corrosive scaling and fouling: 120.00-249.00, 800.00-1599.00}, {Highly corrosive scaling and fouling: 120.00-249.00, 800.00-1599.00}, {Unfit for industrial processes: 250.00-1000.00, 1600.00-10000.00}, {Unfit for industrial processes: 250.00-1000.00, 1600.00-10000.00}; 6dictionary ["Irrigation"] = ← {cond, tds, sal} = {Excellent for irrigation: 0.00-699.99, 0.00-449.99, 0.00-0.49}, {Moderate hazard for irrigation: 700.00-2999.99, 500.00-1999.99, 0.50-1.99}, {Hazard for irrigation: 3000.00-10000.00, 2000.00-10000.00, 2.0-10.00};

7 Get feature dictionary with respect to feature type v using the parameter classification table;

8 **For** each item (keyword, value_range) in the feature dictionary;

Fig. 3.6 Algorithm 3: Interpreting semantic meaning of a multiple feature.

3.4 A river Heavy Metal Evaluation Index (rHMEI) and semantic space creation

In this subsection, the study proposes a method for classification and interpretation of monitoring data by using the dimensional subspace of a river water-quality parameter (heavy metal) in the rSPA process.

The river Heavy Metal Evaluation Index (rHMEI) in a river Sensing Processing Actuation process is created by using the multi-dimensional space of heavy metal substances. This was applied to Pori's water resource (Finland) and evaluated the effect of heavy metal concentration (nine parameters). In this case, the rHMEI is effective for analyzing water quality in several contexts.

In the analysis system integrates special knowledge resources in environmental analysis and semantic computing for evaluating water-quality in terms of heavy metals. In particular, this is the interpretation of numerical values of heavy metals in semantic wording.

The procedure is (1) the process index creation (rHMEI) by using the multi-heavy metal parameter, and (2) the process of data analysis by using an index in multi-dimensional subspace.

3.4.1 The Procedure of Index Creation (rHMEI) by Using Multi-heavy Metal Parameters

The first procedure of this subsection, this study shows the pollutant-environmental variable, environmental indicator monitoring, public information, and scientific research.

The environmental indicator is summarized data from the information into the simplest form, which did not deviate data results. This study applies and realizes the environmental indicator on an increasing scale, which refers to highly pollutant index on the environmental evaluation indices. The creating steps is outlined as following:

- The first step, the study surveys the characteristic of heavy metals as the toxicity parameter and availability in the hydrologic environment and design several parameters for index creation.
- The second step, the study implements the index that consists of sub-indices in the environmental indicator of heavy metals. The summary of each sub-index is shown in Figure 3.7.

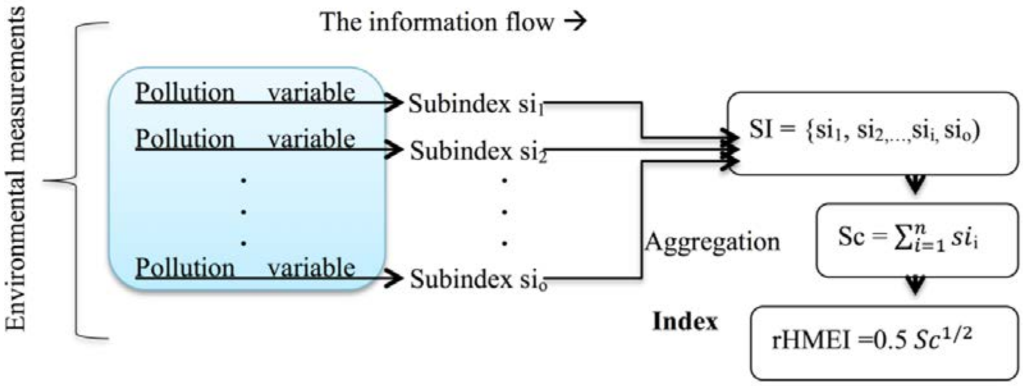


Fig. 3.7 The information flow in rHMEI creation.

The set of subindices is represented as
$SI = \{si_1, si_2, si_3, ..., si_i, si_o\}$
In this implementation o = 9
Where
V_{si-obs} is an observation value of the i^{th} heavy metal parameter,
$V_{si-thres}$ is a threshold value of the i^{th} heavy metal parameter
the subindex si is calculated using the following formulas in Eq. 3.6

$$si_i = \frac{V_{si_i-obs}}{V_{si_i-thres}} \tag{3.6}$$

The total score of subindex Sc is calculated as a summation of the ratio between observation value of V_{si-obs} and the threshold value of $V_{si-thres}$

$$Sc = \sum_{i=1}^{n} si_i^2 \tag{3.7}$$

- The third step, the study presents the related implementation of the subindex with the variable of substance. A heavy metal is a hazardous substance and causes acute effects in concentrations of a substance over the threshold value. The dose response curve of a heavy metal is a substance's concentration represented as a linear function with an increasing scale that is shown in Figure 3.8 (a). When the concentration of the heavy metal is more than threshold value, acute damage is caused. It is shown in Figure 3.8 (b).

- The fourth step, the research studies several methods for aggregation of subindices and uses the root mean square for eliminating ambiguous and eclipsing situations. It is shown in Figure 3.9

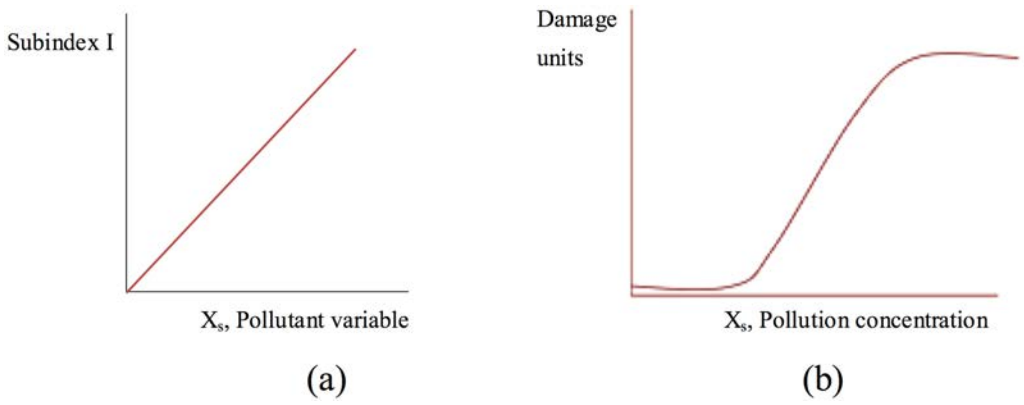


Fig. 3.8 The dose response curve of (a) substance's concentration characteristic (segmented in the linear function) and (b) the damage functions of the heavy metal.

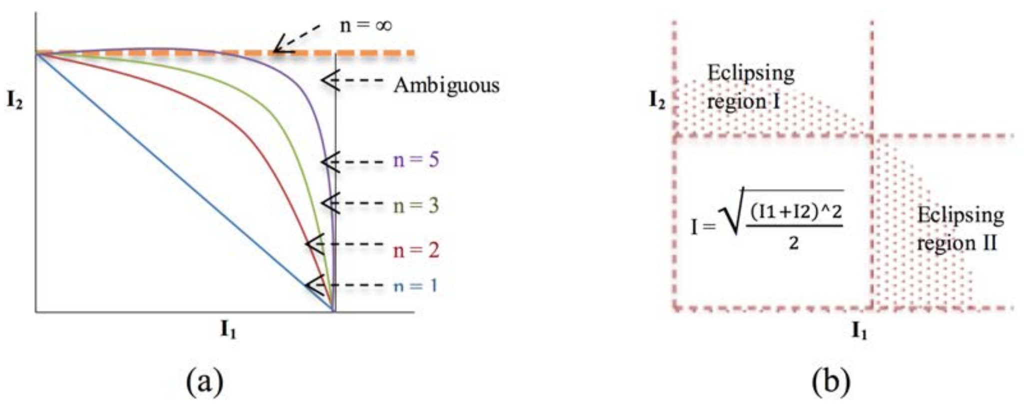


Fig. 3.9 The subindex summarization type of (a) root sum power and (b) root mean square efficiency.

The rHMEI is a mathematics instrument used to aggregate diverse heavy metal parameters and their multi-dimensional aspects into a single score. The equation for calculating the rHMEI is defined in Eq. 3.8

Where

rHMEI is a river Heavy Metal Evaluate index in each context (Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water),

Sc is a total score of the subindex in each context (Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water).

$$rHMEI = 0.5(Sc)^{1/2} \tag{3.8}$$

The international standard and/or maximum values are shown in Table 3.4.

Table 3.4 The international standard threshold value of heavy metal parameters.

Context	Parameter								
	As	Cd	Cr	Cu	Fe	Pb	Hg	Ni	Zn
Aquatic life	10	1	1	4	300	7	0.003	25	25
Livestock and Wildlife	50	100	2000	1500	200	100	2	-	-
Irrigation	100	100	100	200	200	5000	1	200	2000
Industry	50	100	2000	1500	1000	100	2	-	-
Estuary Basic Water	500	5	500	500	3000	500	0.5	500	50000

Where

As is a standard threshold value of arsenic parameters (As^{3+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Cd is a standard threshold value of cadmium parameters (Cd^{2+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Cr is a standard threshold value of chromium parameters (Cr^{6+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Cu is a standard threshold value of copper parameters (Cu^{2+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Fe is a standard threshold value of iron parameters (Fe^{3+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water, Pb is a standard threshold value of lead parameters (Pb^{2+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Hg is a standard threshold value of mercury parameters (Hg^{+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

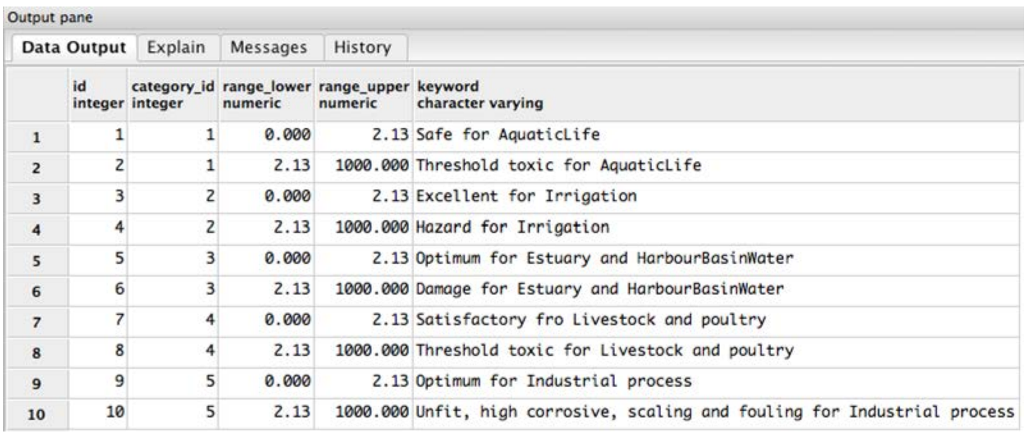
Ni is a standard threshold value of nickel parameters (Ni^{2+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water,

Zn is a standard threshold value of zinc parameters (Zn^{2+}) in the contexts of Aquatic life, Livestock and Wildlife, Irrigation, Industry and Estuary Basic water

The rHMEI classification is on two levels based on the international standard and/or maximum values as shown in Table 3.5 and Figure 3.10 as classification criteria.

Table 3.5 The example of calculation for heavy metal parameters based on the international standard threshold value (for classification).

Parameter	V_{si-obs}	$V_{si-thres}$	si	si^2	Sc	rHMEI
As	10.00	10.00	1.00	1.00		
Cd	1.00	1.00	1.00	1.00		
Cr	1.00	1.00	1.00	1.00		
Cu	4.00	4.00	1.00	1.00		
Fe	300.00	300.00	1.00	1.00		
Pb	7.00	7.00	1.00	1.00		
Hg	0.003	0.003	1.00	1.00		
Ni	25.00	25.00	1.00	1.00		
Zn	5.00	5.00	1.00	1.00		
					9	2.13


Output pane

Data Output | Explain | Messages | History

	id integer	category_id integer	range_lower numeric	range_upper numeric	keyword character varying
1	1	1	0.000	2.13	Safe for AquaticLife
2	2	1	2.13	1000.000	Threshold toxic for AquaticLife
3	3	2	0.000	2.13	Excellent for Irrigation
4	4	2	2.13	1000.000	Hazard for Irrigation
5	5	3	0.000	2.13	Optimum for Estuary and HarbourBasinWater
6	6	3	2.13	1000.000	Damage for Estuary and HarbourBasinWater
7	7	4	0.000	2.13	Satisfactory fro Livestock and poultry
8	8	4	2.13	1000.000	Threshold toxic for Livestock and poultry
9	9	5	0.000	2.13	Optimum for Industrial process
10	10	5	2.13	1000.000	Unfit, high corrosive, scaling and fouling for Industrial process

Fig. 3.10 The rHMEI classification of each context.

The example of calculation for heavy metal parameters based on the international standard threshold value for aquatic life context is shown in Table 3.6

Where

V_{si-obs} is equal $V_{si-thres}$ is a threshold value of the i^{th} heavy metal parameter,

si is a subindex of the i^{th} heavy metal parameter,

Sc is a total score of subindex in each context,

$rHMEI$ is a river Heavy Metal Evaluate index in each context

Table 3.6 The example of calculation for heavy metal parameters based on the international standard threshold value and real observation data (for aquatic life context).

Parameter	V_{si-obs}	$V_{si-thres}$	si	si^2	Sc	rHMEI
As	0.72	10.00	0.072	0.005		
Cd	0.40	1.00	0.04	0.002		
Cr	1.20	1.00	1.20	1.44		
Cu	2.40	4.00	0.60	0.36		
Fe	1800	300.00	6.00	36.00		
Pb	0.45	7.00	0.07	0.004		
Hg	0.00	0.003	0.00	0.00		
Ni	4.50	25.00	0.18	0.03		
Zn	7.90	5.00	1.58	2.497		
					40.34	4.49
						Threshold toxic for aquatic life

3.4.2 The Procedure of Data Analysis by rHMEI on rSPA Processes

A second procedure used for analyzing data on rSPA processes, this research applies the rHMEI in a processing part on the rSPA processes by using PostgreSQL. It is shown in Figure 3.11

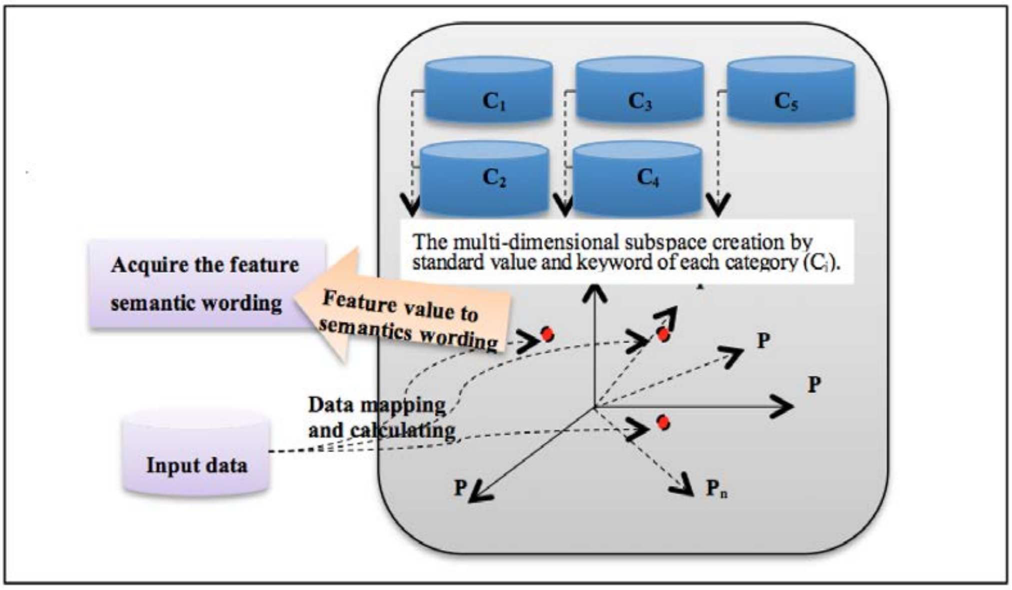


Fig. 3.11 The second procedure used for analyzing data on rSPA processes.

The processing steps are explained in below

- The first step: the process for creating the 5 contexts, which is aquatic life (C_1), irrigation (C_2), estuary and harbor basin water (C_3), livestock and wildlife (C_4), and industry (C_5) by using multi-heavy metal parameters. The wording creation based on standard threshold toxic value in the database. An effective wording for interpretation is safe and threshold toxic,
- The second step: the process for selecting the multi-heavy metal parameters that relate to the category group and creating the multi-dimensional semantic space.
- The third step: this process is for mapping input data and calculating the rHMEI by using the multi-dimensional semantic space in contexts.
- The fourth step: this process is for executing feature word processing by selecting the candidate important word from the heavy metal parameter levels quality field.

3.5 Semantic-ordering functions

In this subsection, this research proposes functions for analyzing and evaluating the water quality by establishing the professional knowledge level databases in water-quality analysis, semantic space creation: a proposed dynamic dimension for river water-quality interpretation, a semantic space parameter-relatedness weighting method of diverse river water-quality variability, and semantic-ordering functions creating for multiple parameters from the increasing and decreasing parameters.

Semantic ordering is analyzed spatial-dynamics environmental changes in multiple contexts. As for the experimental study, four places have been selected for the study areas; (1) Hawaii (USA), (2) Pori, (Finland), (3) Riga (Latvia), and (4) Vientiane (Laos) between March and September 2016. The result indicates that by using semantic-ordering functions, analyzing the meta-level knowledge of the database system for water-quality data, it is possible to identify the different water qualities in different places from a global point of view and present the global-scale ranking in water quality.

This research is integrating deep knowledge of water-quality and semantic computing in MMM and it is the first trial to apply nature to MMM. The important of water-quality analysis with semantic computing is to give the meaning to the water-quality and map the meaning all of them into multi-dimensional semantic space. The most important to define water-quality meaning (for example k levels) needs professional knowledge, scientific evidence, several experiences, and fieldworks on water-quality for mapping into multi-dimensional space. The main core of water-quality analysis with semantic computing is (1) it investigates the relation between parameter and water-quality meaning, and (2) parameter values are related with meanings, those are expressed by multidimensional semantic space. There are 5 steps to define m levels of classification as below

- Step 1: To set p parameters based on national water-quality Handbook as a feature.
- Step 2: To set m meaningful words of water-quality based on scientific journal, which are defined by p features combination as a level (for k levels).
- Step 3: Assigning the weight to each feature of the level, which are defined by this method. Features weight are used to normalize the levels of classification and calculate the water-quality factor.

- Step 4: The relation between features and levels is expressed by water-quality factor as a range of function.
- Step 5: Meaningful words are mapped to multi-dimensional semantic space.

The process to define water-quality meaning and map to multi-dimensional semantic space is shown in Figure 3.12

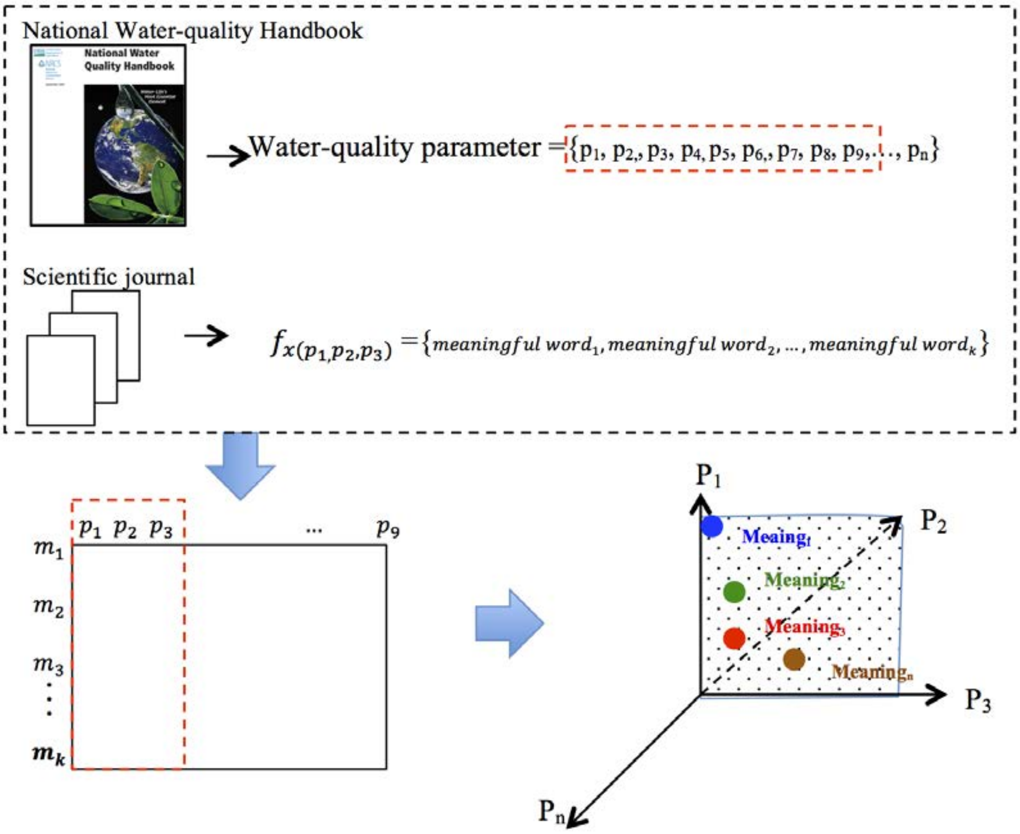


Fig. 3.12 The process to define water-quality meaning and map to multi-dimensional semantic space.

This research creates the semantic context that is based on deep knowledge of environmental system design and water-quality assessment. The step to create the semantic context is outlined as follows:

3.5.1 Design raw data vector (RDV)

The study creates the raw data vector of multiple water-quality parameters, in particular the focusing on the significant parameters in term of physical, chemical, and biological characteristics as an important feature for analyzing and the water-quality evaluation.

The raw data vector in this subsection consists of pH, dissolved oxygen (DO), conductivity, (cond), salinity, total dissolved solid (tds), turbidity, Escherichia coli, Enterococci, and Coliform bacteria etc. The RDV is shown in Table 3.7

Table 3.7 The Raw Data Vector(RDV) design.

P_a	P_b	P_c	P_d	P_e	P_f	P_g	P_h	P_i	...	P_n	RDV
P_{a1}	P_{b1}	P_{c1}	P_{d1}	P_{e1}	P_{f1}	P_{g1}	P_{h1}	P_{i1}	...	P_{n1}	RDV_1
P_{a2}	P_{b2}	P_{c2}	P_{d2}	P_{e2}	P_{f2}	P_{g2}	P_{h2}	P_{i12}	...	P_{n2}	RDV_2
P_{a3}	P_{b3}	P_{c3}	P_{d3}	P_{e3}	P_{f3}	P_{g3}	P_{h3}	P_{i3}	...	P_{n3}	RDV_3
P_{a4}	P_{b4}	P_{c4}	P_{d4}	P_{e4}	P_{f4}	P_{g4}	P_{h4}	P_{i14}	...	P_{n4}	RDV_4
P_{a5}	P_{b5}	P_{c5}	P_{d5}	P_{e5}	P_{f5}	P_{g5}	P_{h5}	P_{i5}	...	P_{n5}	RDV_5
P_{a6}	P_{b6}	P_{c6}	P_{d6}	P_{e6}	P_{f6}	P_{g6}	P_{h6}	P_{i6}	...	P_{n6}	RDV_6
P_{a7}	P_{b7}	P_{c7}	P_{d7}	P_{e7}	P_{f7}	P_{g7}	P_{h7}	P_{i7}	...	P_{n7}	RDV_7

Where
P_a is pH,
P_b is Conductivity,
P_c is Dissolved Oxygen (DO),
P_d is Salinity,
P_e is Total Dissolved Solid (TDS),
P_f is Turbidity,
P_g is Escherichia coli,
P_h is Enterococci,
P_i is Coliform bacteria,
P_n is n parameter,
RDV is raw data vector of factor set

3.5.2 Realize and create the knowledge related interpret context based on deep knowledge in design environmental system and water-quality assessment

The study realizes the water-quality criteria based on scientific evidence and technical information based on professional knowledge for the particular water resource component in numerical data and semantic features data (narrative descriptions). The main purpose of this approach is to create an automatic human-interpreting system by integrating professional's knowledge from environmental engineering and semantic computing, which is a new human interpretation of environments to inform the actual water-quality level of the water body for society by transforming the sensor-value information into language information.

Established new knowledge representation of professional's knowledge in water- quality analysis field

The professional's knowledge is represented in new knowledge from this study. It integrates the international standards and scientific statements in targeted areas to reflect the real ground condition of water by using the value/range from the scientific experimental study. It is shown in Figure 3.13.

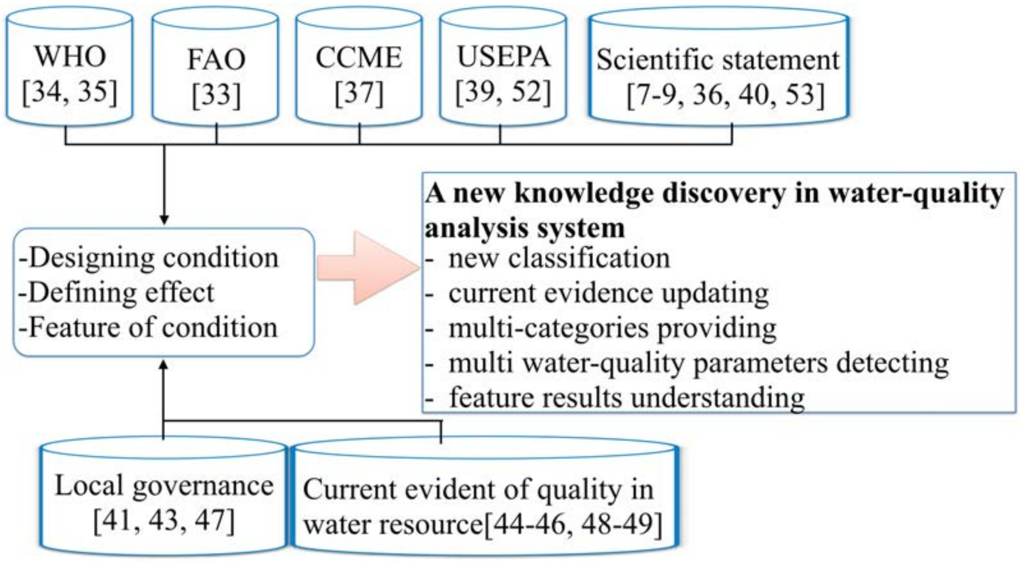


Fig. 3.13 The strategy and process to establish new knowledge representation of specialists knowledge in water-quality analysis field.

The summaries of context and design context are based on deep knowledge in environmental system design and water-quality assessment [33–35], [37], [40, 41], and are shown in Table 3.8, Table 3.9, and Table 3.10

Where
pH is Potential of Hydrogen ion,
$Cond$ is Conductivity,
DO is Dissolved Oxygen ,
$Sali$ is Salinity,
TDS is Total Dissolved Solid ,
$Turb$ is Turbidity,
$E.coli$ is Escherichia coli,
$Entero$ is Enterococci,
$Coliform$ is Coliform bacteria
Table 3.10 shows the water-quality criteria and technical information for a particular component of water quality for establish this table.

Table 3.8 The design context based on deep knowledge in design environmental system and water-quality assessment.

Context	Feature	An effect
Agriculture	Cond	Damaging to growth or degradation products of plant.
	Sali	Damaging to an evapotranspiration (ET) of crop, crop root-zoon, and yields loss.
	TDS	Causing death, sickness, or impaired growth or degradation products of plant.
Aquatic life	DO	Decreasing respiration and feeding activities of aquatic systems. Moreover, reducing the cleanness quality and harmful impact on drinking water.
Drinking	pH	Causing cleanliness problems. Causing alkali taste in water.
	TDS	Direct on the intestinal mucous membrane, metabolism, and mineral homeostasis or other body functions, and practically zero calcium and magnesium intake.
	Turb	Reducing the cleanness quality and having a harmful impact on drinking water.
Fish	pH	Damaging to assimilate the food consumed, and the greater the stress.
Industry	Cond	Damaging equipment (encrusts and/or corrodes surfaces of metal) and effects to interrupt chemical processes, and impairment of product quality.
	pH	Damaging equipment (corrosive, scaling, and deposits in equipment).
	TDS	Damaging to process by indirectly interfacing with the proper function of several industrial processes causing damage and chronic corrosion, scaling, and fouling of equipment, and dietary increased intake of toxic metals leached from water pipes.

Table 3.9 The design context based on deep knowledge in design environmental system and water-quality assessment (*Cont*.).

category	Feature	An effect
Irrigation	Cond	Causing physical upset and/or death of livestock and poultry. The water quality is affected impacts the growth stage of crops, the osmosis process in crops, and reduces the growth stage by mechanism of water uptake.
	Sali	Water quality affected occurring in the growth stage of crop, effects the osmosis process in crops and reduces growth stage by mechanism of water uptake.
	TDS	Causing death, sickness, or impaired growth or degradation of livestock and poultry. Damaging to crops by causing accumulation of salts in the root zone, loss of permeability of the soil due to excess sodium Na^{+} or calcium Ca^{2+} leaching.
Recreation	E. coli	Causing illness or disease from recreational activities in contaminated fresh water such as waterborne diseases, Gastrointestinal tract disease (GI) illness, and skin disease. The higher concentration of Escherichia coli causes higher risk of illness such as upper respiration illness and infected cuts. The lower concentration of Escherichia coli affects human skin causing rashes, eye ailments, and earache.
	Entero	Causes illness or disease from recreational activities in contaminated fresh and marine water such as waterborne disease, GI illness, and skin disease. The higher concentration of Escherichia coli causes higher risk of illness such as upper respiration illness and infected cuts. The lower concentration of Escherichia coli affects human skin causing rashes, eye ailments, and earache.
	Coliform	Causing illness or GI disease in animals and humans.

Table 3.10 A summary of the design context based on deep knowledge in design environmental system and water-quality assessment.

Context	Feature$_1$ (Cond)	Feature$_2$ (DO)	Feature$_3$ (pH)	Feature$_4$ (Sal)	Feature$_5$ (TDS)	Feature$_6$ (Turb)	Feature$_7$ (E. coli)	Feature$_8$ (Coliform bacteria)	Feature$_9$ (Enterococci)	Semantic meaning
Agriculture	0 – 29			0-0.14	0-149					Excellent for agriculture
	30 – 74			0.15-0.49	150-499					Hazard for sensitive crop
	75 – 224			0.5-1.49	500-1499					Hazard for low tolerance crop
	225 - 499			1.5-2.9	1500-3199					Hazard for high tolerance crop
	500-749			3.0-4.9	3200-5119					Satisfactory for livestock and poultry
	750-1999			5.0-6.9	5200-7039					Hazard for poultry
	2000-15999			7.0-9.9	7040-10239					Unfit for agriculture
	16000-50000			10-50	10240-20000					Suddenly toxic for agriculture
Aquatic life		7.0 -15								Abundant aquatic life
		6.0 - 6.9								Support growth and activity for aquatic life
		5.0 – 5.9								Support spawning
		3.0 – 4.9								Hazard for aquatic life
		0.0 – 2.9								All aquatic life extinction
Drinking			6.5-8.4		0-199	0-1.9				Optimum for drinking
			5.0-6.4, 8.5-9.1		200-599	2.0-4.9				Hazard and chronic toxic for drinking
			0.0-4.9 9.2-14		600-1000	5.0-10.0				Unfit and toxic for drinking
Fish			6.5-8.1							Abundant for fish
			6.0-6.4							Optimum for fish and shrimp
			5-5.9							Bacteria and plankton being disappear
			4.0-4.9, 8.2-10.4							Hazard for fish and salmon dying
			0-3.9, 10.5-14.0							All fish extinction
Industry	0-29		6.5-7.9		0-199					Optimum for industrial process
	30-49		6.0-6.4, 8.0-8.9		200-349					Slightly corrosive scaling and fouling
	50-119		5.0-5.9, 9.0-9.9		350-799					Moderate corrosive scaling and fouling
	120-249		4.0-4.9, 10.0-11.9		800-1599					Highly corrosive scaling and fouling
	250-1000		0.0-3.9, 12.0-14.0		1600-10000					Unfit for industrial process
Irrigation	0-69			0-0.4	0-499					Excellent for irrigation
	70-299			0.5-1.9	500-1999					Moderate hazard for irrigation
	300-10000			2.0-15.0	2000-10000					Hazard for irrigation
Recreation							0-100	0-500	0-40	Litter risk of illness
							101-1000	501-10000	41-400	Moderately risk of illness
							1001-10000	10001-100000	401-4000	Critical risk of illness
							10001-100000	100001-1000000	4001-40000	Strongly risk of illness
							100001-1000000	1000001-10000000	40001-100000	Excessively risk of illness

The main points of this table are the new classification, current evidence updating, multi-context provision, multi-water-quality parameters detection, and feature results understanding.

The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the agriculture context is shown in Figure A.1 and the other contexts are shown in Appendix A.

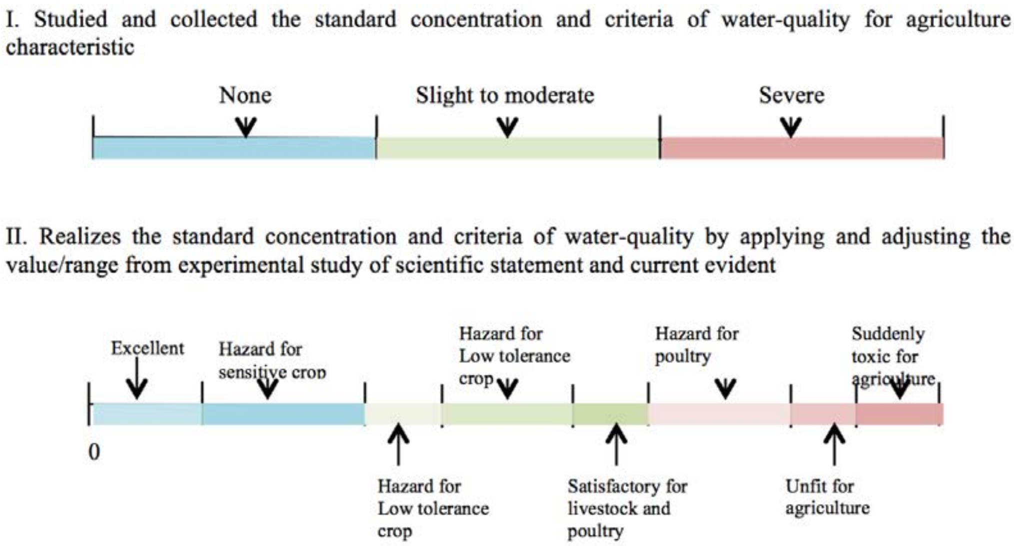


Fig. 3.14 The strategy and process to establish new knowledge representation of specialist's knowledge in agriculture context.

Semantic Context in Water-quality

This semantic context is an effective filter for analyzing and interpreting deep knowledge in environmental system design. This is realized to help scientists and/or trained field workers to better understand that an improved water quality resource correlates to better conditions.

The design and realization of the semantic context for human interpretation is shown in Table 3.11

Where

C_{x1} is the context of "agriculture". In this context, the crucial features are feature$_1$ (cond), feature$_4$ (sal), and feature$_5$ (tds). These features are neglected because they are readily available in quality of water supplies or/and water resources. We point out the specific condition context for different quality needs in the agricultural field. The different range of features are damaged and reduced yield results [21], [33], [36], [40, 41], [42], [43, 44]

C_{x2} is a context of "aquatic life". In this context, feature$_2$ (DO) is an imperative feature of most aquatic organisms as it maintains and provides them with oxygen to carry out and accomplish cellular respiration and the process of photosynthesis [7], [9], [37], [42], [45, 46].
C_{x3} is a context of "drinking". In this context, three features, which are feature$_3$ (pH), feature$_5$ (tds), and feature$_6$ (turb), are used for evaluating the quality and suitability of the water for drinking. The concentration of these features affects dehydration of the tissues (skin), unpleasant mineral taste, hazard and chronic damage to several functions in the human body [8], [35], [41], [42, 47], [48, 49].
C_{x4} is the context of "fish". In this context, feature$_3$ (pH) strongly effects fish. Because small changes in pH can cause hazard to many kinds of fish, which cannot survive or/and reproduce outside of the optimum range [7], [37].
C_{x5} is a context of "industry". In this context, we provide the specific factors of water-quality constituents as feature$_1$ (cond), feature$_3$ (pH), and feature$_5$ (tds). Those features play an important role in industrial processes, equipment and structure, impairment of product quality, and the amount of treated or disposed of wasted generated [7], [41], [42].
C_{x6} is a context of "irrigation". In this context, we are concerned with the factors of feature$_1$ (cond), feature$_4$ (sal), and feature$_5$ (tds). Those features are required both qualitatively and quantitatively and are significant factors for determining water availability for irrigation [7], [9], [42], [50, 51], [52–55].
C_{x7} is a context of "recreation". In this context, we are concerned with factors of feature$_7$ (E. coli), feature$_8$ (Coliform bacteria), and feature$_9$ (Enterococci). Those features are defined as causing risk of illness and disease in recreational activities [56–59].

Table 3.11 The design context based on deep knowledge in designing environmental system and water-quality assessment for human interpretation.

Context	$Factor_1$ (Cond)	$Factor_2$ (DO)	$Factor_3$ (pH)	$Factor_4$ (Sal)	$Factor_5$ (TDS)	$Factor_6$ (Turb)	$Factor_7$ (E.coli)	$Factor_8$ (Coliform)	$Factor_9$ (Enterococci)
C_{x1}	1	0	0	1	1	0	0	0	0
C_{x2}	0	1	0	0	0	0	0	0	0
C_{x3}	0	0	1	0	1	1	0	0	0
C_{x4}	0	0	1	0	0	0	0	0	0
C_{x5}	1	0	1	0	1	0	0	0	0
C_{x6}	1	0	0	1	1	0	0	0	0
C_{x7}	0	0	0	0	0	0	1	1	1

Inner product (characteristic of RDV_i) = $RAV_n \times C_{xn}$

From the semantic context for human interpretation, we design multi-dimension intervals of the water-quality analysis system of each factor as below

Context = $\{C_{x1}, C_{x2}, C_{x3}, ..., C_{xi}, C_{xq}\}$ (In this implementation q = 7)

Each context $\{C_{x1}, C_{x2}, C_{x3}, ..., C_{xi}, C_{xq}\}$ has several levels. The number of levels is different depending on the level (L) of the context C_{xi}, which is represented as

$LC_{xi} = \{LC_{x1}, LC_{x2}, LC_{x3}, ..., LC_{xi}, LC_{xq}\}$

- For multi-dimension intervals for agriculture context (C_{x1}), level-judgment function for agriculture f_{agr} is described as below;

$$f_{agr}(cond,tds,sal)=\begin{cases} LC_{x1} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|0.0\leq cond_{obs}<30.0;\\ & 0.0\leq tds_{obs}<150.0;0.00\leq sal_{obs}<0.15\}\\ LC_{x2} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|30.0\leq cond_{obs}<75.0;\\ & 150.0\leq tds_{obs}<500.0;0.15\leq sal_{obs}<0.50\}\\ LC_{x3} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|75.0\leq cond_{obs}<225.0;\\ & 500.0\leq tds_{obs}<1500.0;0.5\leq sal_{obs}<1.50\}\\ LC_{x4} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|225.0\leq cond_{obs}<500.0;\\ & 1500.0\leq tds_{obs}<3200.0;1.50\leq sal_{obs}<3.00\}\\ LC_{x5} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|500.0\leq cond_{obs}<750.0;\\ & 3200.0\leq tds_{obs}<5120;3.00\leq sal_{obs}<5.00\}\\ LC_{x6} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|750.0\leq cond_{obs}<2000.0;\\ & 5120.0\leq tds_{obs}<7040;5.00\leq sal_{obs}<7.00\}\\ LC_{x7} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|2000.0\leq cond_{obs}<16000.0;\\ & 7040.0\leq tds_{obs}<10340;7.00\leq sal_{obs}<10.00\}\\ LC_{x8} & \leftarrow \{(cond,tds,sal)\in\mathbb{R}^3|16000.0\leq cond_{obs}<50000.0;\\ & 10340.0\leq tds_{obs}<20000.0;10.00\leq sal_{obs}<50.00\} \end{cases}$$

Where

$f_{agr}(cond,tds,sal)$ = $\{LC_{x1}$, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5}, LC_{x6}, LC_{x7}, $LC_{x8}\}$ $\leftarrow$ {Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, Suddenly toxic for agriculture}

$cond_{obs}$ = the observation value of conductivity parameter

tds_{obs} = the observation value of total dissolved solid parameter

sal_{obs} = the observation value of salinity parameter

- For dimension interval for aquatic life context (C_{x2}), level-judgment function for aquatic life f_{aq} is described as below;

$$f_{aq}(do) = \begin{cases} LC_{x1} & \leftarrow \{do \in \mathbb{R} | 7.00 \leq do_{obs} < 15.00\} \\ LC_{x2} & \leftarrow \{do \in \mathbb{R} | 6.00 \leq do_{obs} < 7.00\} \\ LC_{x3} & \leftarrow \{do \in \mathbb{R} | 5.00 \leq do_{obs} < 6.00\} \\ LC_{x4} & \leftarrow \{do \in \mathbb{R} | 3.00 \leq do_{obs} < 5.00\} \\ LC_{x5} & \leftarrow \{do \in \mathbb{R} | 0.00 \leq do_{obs} < 3.00\} \end{cases}$$

Where

$f_{aq}(do)$ = $\{LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5}\} \leftarrow$ {Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, All aquatic life extinction}

do_{obs} = the observation value of dissolved oxygen parameter

- For multi-dimension intervals for drinking context (C_{x3}), level-judgment function for drinking f_{dri} is described as below;

$$f_{dri}(pH, tds, turb) = \begin{cases} LC_{x1} & \leftarrow \{(pH, tds, turb) \in \mathbb{R}^3 | 6.50 \leq pH_{obs} < 8.50; \\ & 0.0 \leq tds_{obs} < 200.0; 0.0 \leq turb_{obs} < 2.0\} \\ LC_{x2} & \leftarrow \{(pH, tds, turb) \in \mathbb{R}^3 | 4.00 \leq pH_{obs} < 6.50 \vee \\ & 8.50 \leq pH_{obs} < 9.20; 200.0 \leq tds_{obs} < 600.0; \\ & 2.0 \leq turb_{obs} < 5.0\} \\ LC_{x3} & \leftarrow \{(pH, tds, turb) \in \mathbb{R}^3 | 0.0 \leq pH_{obs} < 4.00 \vee \\ & 9.20 \leq pH_{obs} < 14.00; 600.0 \leq tds_{obs} < 1000.0; \\ & 5.0 \leq turb_{obs} < 10.0\} \end{cases}$$

Where

$f_{dri}(pH, tds, turb)$ = $\{LC_{x1}, LC_{x2}, LC_{x3}\} \leftarrow$ {Optimum for drinking, Hazard and chronic toxic for drinking, Unfit and toxic for drinking}

pH_{obs} = the observation value of potential of hydrogen ion (pH) parameter

tds_{obs} = the observation value of total dissolved solid parameter

$turb_{obs}$ = the observation value of turbidity parameter

- For dimension interval for fish context (C_{x4}), level-judgment function for fish f_{fish} is described as below;

$$f_{fish}(pH) = \begin{cases} LC_{x1} & \leftarrow \{pH \in \mathbb{R} | 6.50 \leq pH_{obs} < 8.20\} \\ LC_{x2} & \leftarrow \{pH \in \mathbb{R} | 6.00 \leq pH_{obs} < 6.50\} \\ LC_{x3} & \leftarrow \{pH \in \mathbb{R} | 5.00 \leq pH_{obs} < 6.00\} \\ LC_{x4} & \leftarrow \{pH \in \mathbb{R} | 4.00 \leq pH_{obs} < 5.00 \vee 8.20 \leq pH_{obs} < 10.50\} \\ LC_{x5} & \leftarrow \{pH \in \mathbb{R} | 0.00 \leq pH_{obs} < 4.00 \vee 10.50 \leq pH_{obs} < 14.00\} \end{cases}$$

Where

$f_{fish}(ph)$ = $\{LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5}\} \leftarrow$ {Abundant for fish, Optimum for fish and shrimp, Bacteria and plankton being disappear, Hazard for fish and salmon dying, All fish extinction}

pH_{obs} = the observation value of potential of hydrogen ion (pH) parameter

- For multi-dimension intervals for industry context (C_{x5}), level-judgment function for industry f_{ind} is described as below;

$$f_{ind}(pH, cond, tds) = \begin{cases} LC_{x1} & \leftarrow \{(pH, cond, tds) \in \mathbb{R}^3 | 6.5 \leq pH_{obs} < 8.0; \\ & 0.0 \leq cond_{obs} < 30; 0 \leq tds_{obs} < 200.0\} \\ LC_{x2} & \leftarrow \{(pH, cond, tds) \in \mathbb{R}^3 | 6.0 \leq pH_{obs} < 6.5 \vee \\ & 8.0 \leq pH_{obs} < 9.0; 30.0 \leq cond_{obs} < 50.0; \\ & 200.0 \leq tds_{obs} < 350.0\} \\ LC_{x3} & \leftarrow \{(pH, cond, tds) \in \mathbb{R}^3 | 5.0 \leq pH_{obs} < 6.0 \vee \\ & 9.0 \leq pH_{obs} < 10.0; 50.0 \leq cond_{obs} < 120.0; \\ & 350.0 \leq tds_{obs} < 800.0\} \\ LC_{x4} & \leftarrow \{(pH, cond, tds) \in \mathbb{R}^3 | 4.0 \leq pH_{obs} < 5.0 \vee \\ & 10.0 \leq pH_{obs} < 12.0; 120.0 \leq cond_{obs} < 250.0; \\ & 800.0 \leq tds_{obs} < 1600.0\} \\ LC_{x5} & \leftarrow \{(pH, cond, tds) \in \mathbb{R}^3 | 0.0 \leq pH_{obs} < 4.0 \vee \\ & 12.0 \leq pH_{obs} < 14.0; 250.0 \leq cond_{obs} < 1000.0;\} \\ & 1600.0 \leq tds_{obs} < 10000.0\} \end{cases}$$

Where

$f_{ind}(pH, cond, tds)$ = {LC_{x1}, LC_{x2}, LC_{x3}, LC_{x4}, LC_{x5}} $\leftarrow$ {Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, Unfit for industrial process}.

pH_{obs} = the observation value of potential of hydrogen (pH) parameter

$cond_{obs}$ = the observation value of conductivity parameter

tds_{obs} = the observation value of total dissolved solid parameter

- For multi-dimension intervals for irrigation context (C_{x6}), level-judgment function for irrigation f_{irri} is described as below;

$$f_{irri}(cond, tds, sal) = \begin{cases} LC_{x1} & \leftarrow \{(cond, tds, sal) \in \mathbb{R}^3 | 0.0 \leq cond_{obs} < 70.0; \\ & 0.0 \leq tds_{obs} < 500.0; 0 \leq sal_{obs} < 0.5\} \\ LC_{x2} & \leftarrow \{(cond, tds, sal) \in \mathbb{R}^3 | 70.0 \leq cond_{obs} < 300.0; \\ & 500.0 \leq tds_{obs} < 2000.0; 0.5 \leq sal_{obs} < 2.0\} \\ LC_{x3} & \leftarrow \{(cond, tds, sal) \in \mathbb{R}^3 | 300.0 \leq cond_{obs} < 10000.0; \\ & 2000.0 \leq tds_{obs} < 10000.0; 2.0 \leq sal_{obs} < 15.0\} \end{cases}$$

Where

$f_{irri}(pH, cond, tds)$ = {LC_{x1}, LC_{x2}, LC_{x3}} $\leftarrow$ {Excellent for irrigation, Moderate hazard for irrigation, Hazard for irrigation}

$cond_{obs}$ = the observation value of conductivity parameter

tds_{obs} = the observation value of total dissolved solid parameter

sal_{obs} = the observation value of salinity parameter

- For multi-dimension intervals for recreation context (C_{x7}), level-judgment function for recreation f_{rec} is described as below;

$$
f_{rec}(E.coli, Coli, Enter) = \begin{cases} LC_{x1} & \leftarrow \{(E.coli, Coli, Enter) \in \mathbb{R}^3 | 0.0 \leq E.coli_{obs} \\ & < 101.0; 0.0 \leq Coli_{obs} < 361.0; 0 \leq Enter_{obs} < 41.0\} \\ LC_{x2} & \leftarrow \{(E.coli, Coli, Enter) \in \mathbb{R}^3 | 101.0 \leq E.coli_{obs} \\ & < 1001.0; 361.0 \leq Coli_{obs} < 8601.0; \\ & 41.0 \leq Enter_{obs} < 401.0\} \\ LC_{x3} & \leftarrow \{(E.coli, Coli, Enter) \in \mathbb{R}^3 | 1001.0 \leq E.coli_{obs} \\ & < 10001.0; 8601.0 \leq Coli_{obs} < 86001.0; \\ & 401.0 \leq Enter_{obs} < 4001.0\} \\ LC_{x4} & \leftarrow \{(E.coli, Coli, Enter) \in \mathbb{R}^3 | 10001.0 \leq E.coli_{obs} \\ & < 100001.0; 86001.0 \leq Coli_{obs} < 860001.0; \\ & 4001.0 \leq Enter_{obs} < 40001.0\} \\ LC_{x5} & \leftarrow \{(E.coli, Coli, Enter) \in \mathbb{R}^3 | 100001.0 \leq E.coli_{obs} \\ & < 1000000.0; 860001.0 \leq Coli_{obs} < 1000000.0; \\ & 40001.0 \leq Enter_{obs} < 1000000.0\} \end{cases}
$$

Where

$f_{rec}(E.coli, Coli, Enter)$ = $\{LC_{x1}$, LC_{x2}, LC_{x3}, LC_{x4}, $LC_{x5}\} \leftarrow$ {Little risk of illness, Moderately risk of illness, Critical risk of illness, Strongly risk of illness, Excessively risk of illness}

$E.coli_{obs}$ = the observation value of E. coli parameter

$Coli_{obs}$ = the observation value of Coliform bacteria parameter

$Enter_{obs}$ = the observation value of Enterococci parameter

From the function range of context category, we can create step function of each context, which is shown in Figure 3.15 as an example

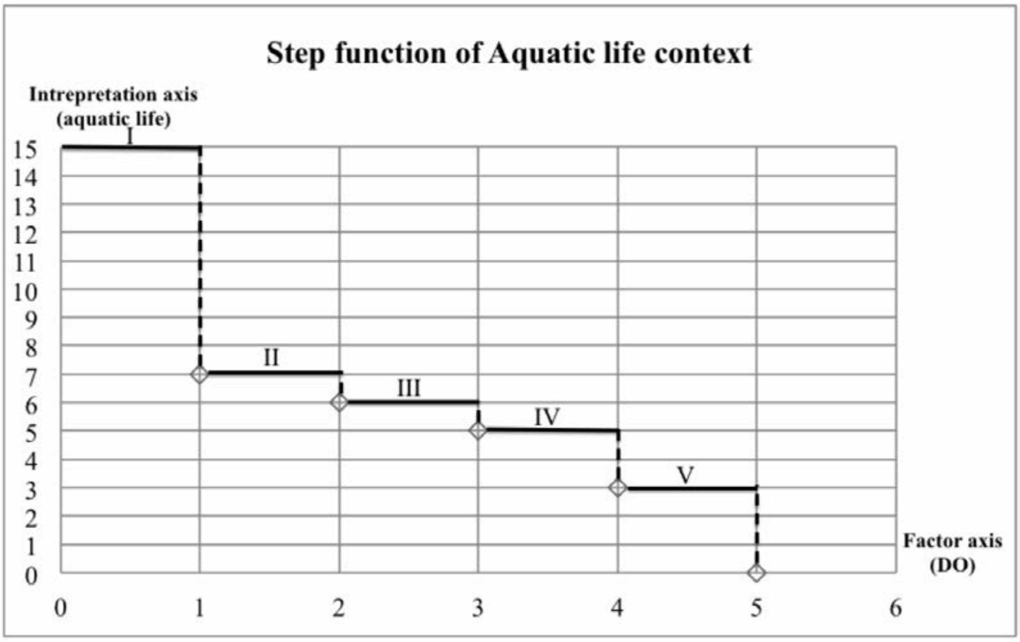


Fig. 3.15 The step function for aquatic life interpreting context.

3.5.3 Semantic Computing in Water-quality Analysis

Generally today, there is only physical space analysis for water-quality analysis. Also, purposes are insufficient for the various contexts for dynamic analysis of the same data. Therefore, semantic computing becomes very useful for water-quality analysis in the dynamic water aspect.

This study integrates the physical space of water-quality analysis, semantic computing, and cyber space into a single framework that has not been done by previous research.

The original idea of semantic computing in the MMM is used to find different data items with similar meaning or to acquire the different data meanings of an item [12]. There are 4 original ideas of MMM: (1) Dimensional Space Creation. (2) Data Mapping to the Semantic Space. (3) Subspace-selection according to context. (4) Matrix-based calculation for ranking, clustering, and classification with a semantic context in an independent way. This work realizes and proposes an automatic system for analyzing various databases and different categories (context) within the dynamic subspace by using context and mathematic formulas for calculation. The multi-dimensional subspace of the water-quality parameters is shown in Figure 3.16

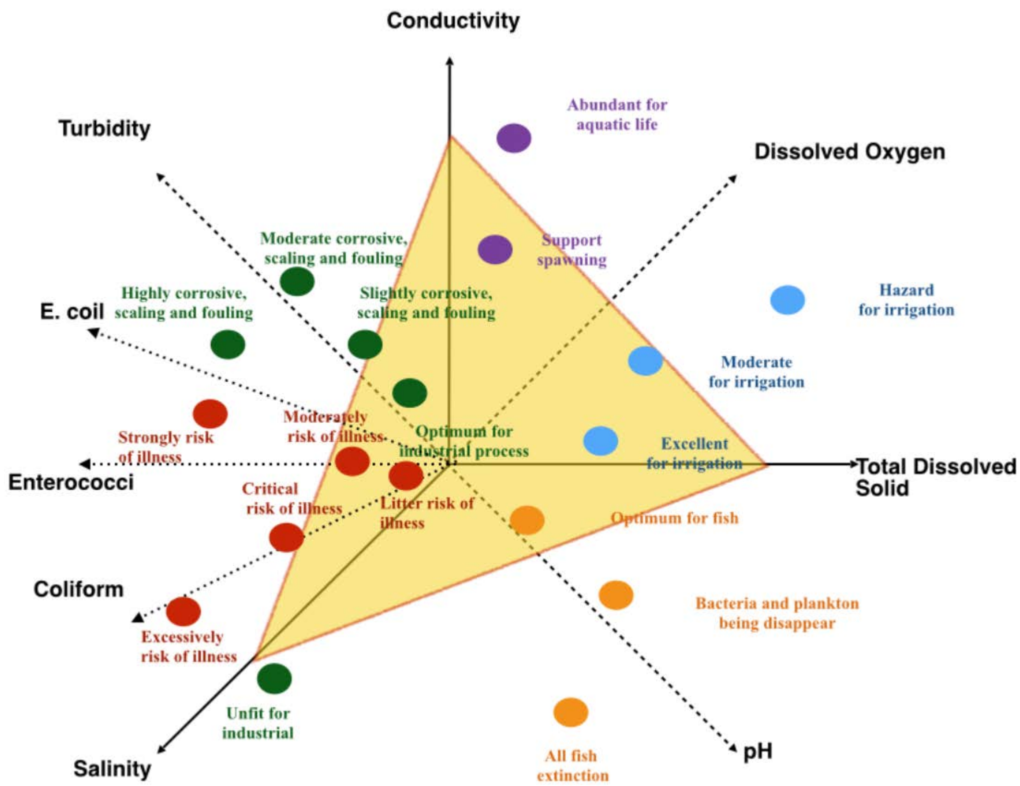


Fig. 3.16 The multi-dimensional subspace of water-quality parameter.

3.5.3.1 Semantic space creation: proposed dynamic dimensions for river water-quality interpretation.

In this implementation, water-quality data are environmental data, which are independent of each other. This research declares each parameter/vector as orthogonal. After all, water-quality data are created in dimensional space. This is shown in Figure 3.17

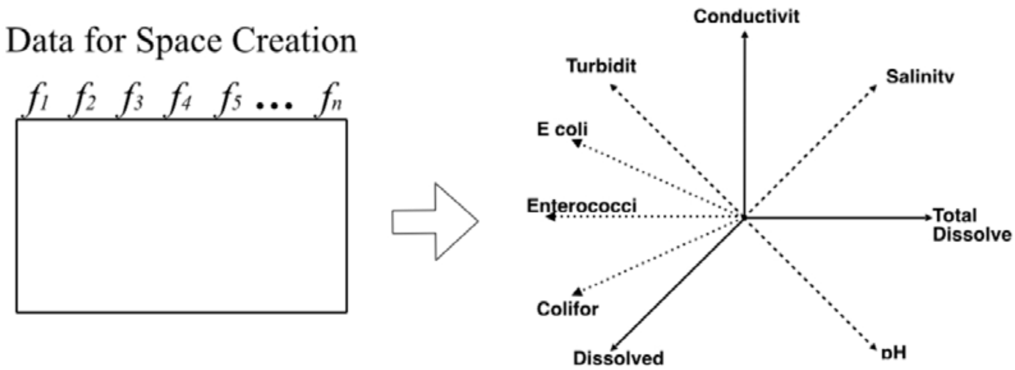


Fig. 3.17 The Dimensional Space Creation.

3.5.3.2 Data Mapping to the Semantic Space

The next important point is the data mapping into semantic space. The space is used to determine the semantic meaning in a highly adjustable manner. On the one hand, one meaning might have one or three dimensions while another might need four dimensions or more. Data Mapping to the Semantic Space is shown in Figure 3.18

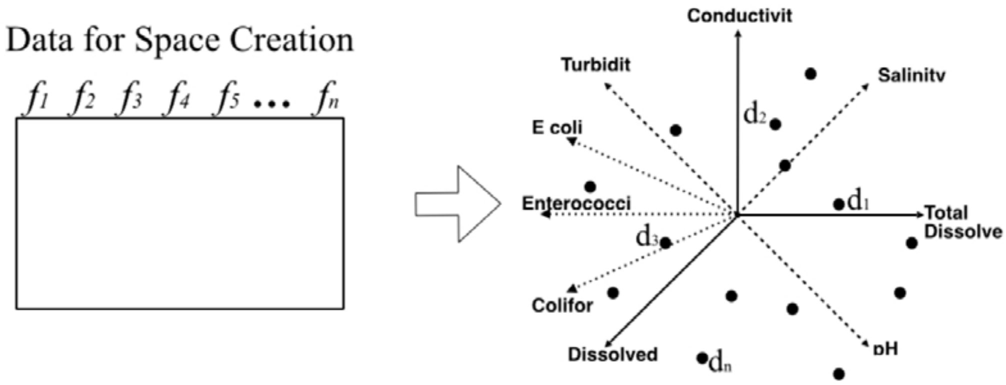


Fig. 3.18 The Data Mapping to the Semantic Space.

3.5.3.3 Subspace-selection according to context

In this step, our new approach is in the subspace selection in the water-quality analysis. As a consequence of previous contexts for water-quality analysis, the subspace selection becomes important for special context analysis. Subspace selection according to context is shown in Figures 3.19, 3.20, and 3.21.

3.5.3.4 Matrix-based calculation for ranking, clustering, and classification with semantic context in an independent way

In this calculation, we proposed a semantic space parameter-relatedness weighting method of diverse river water-quality variability.

For example, in the implementation case of an agricultural context, it uses a radius measurement to acquire the new word and meaning. This is shown in Figure 3.22.

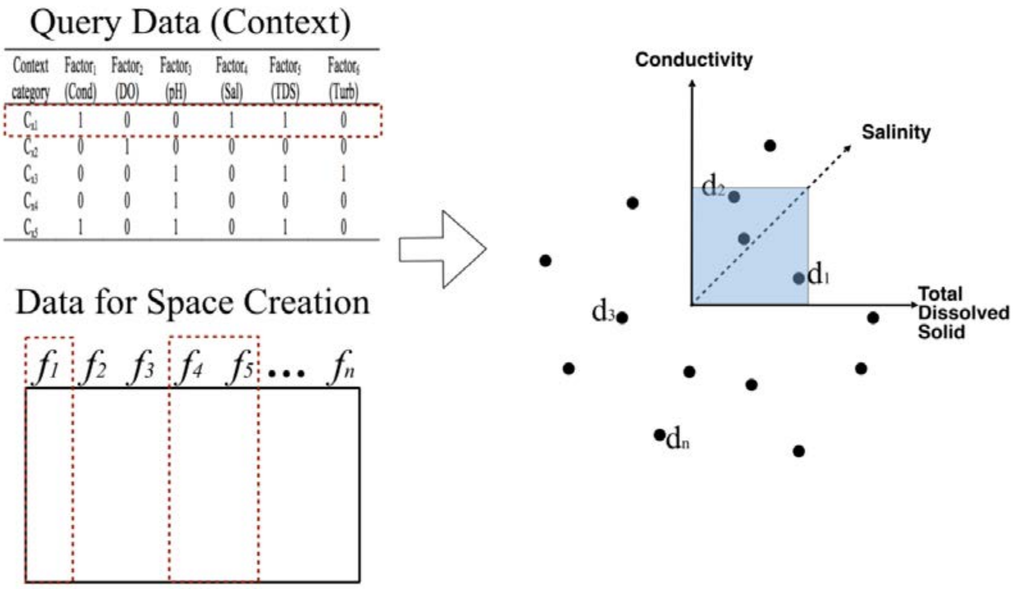


Fig. 3.19 The Subspace-selection according to context.

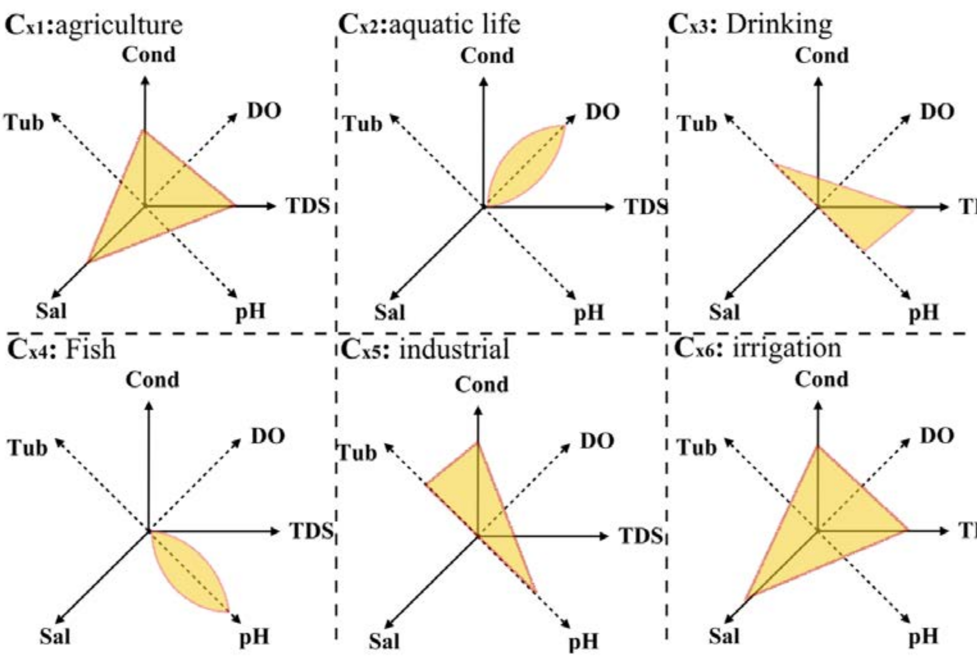


Fig. 3.20 The Subspace-selection according to context in each context.

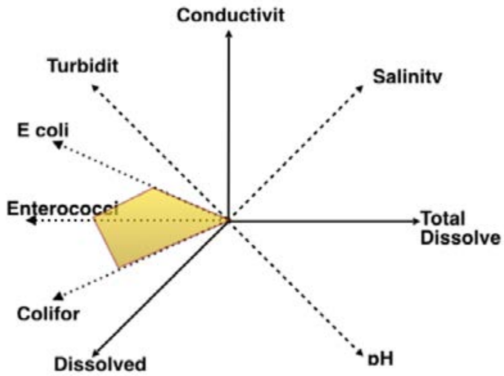


Fig. 3.21 The Subspace-selection according to context in each context ($Cont.$).

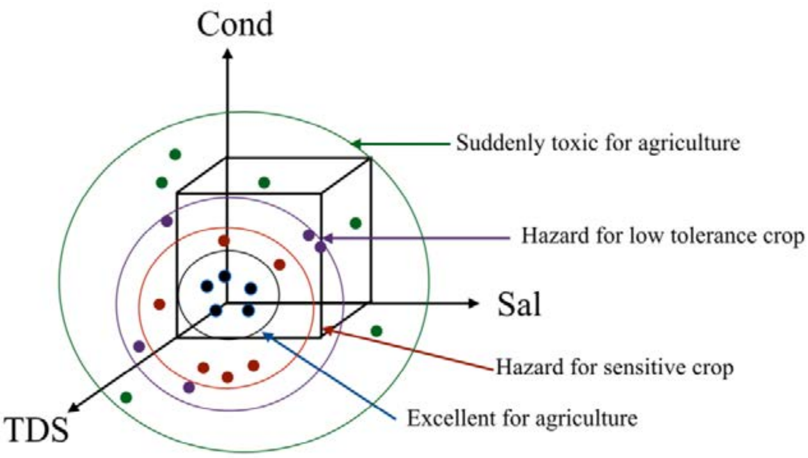


Fig. 3.22 The Matrix-based calculation for ranking, clustering and classification with semantic context independent way.

3.5.3.4-1 Creation of Water-quality Factor

Calculating sub-factor

Several water parameters with different units and dimensions are converted into sub-factor P with a simple scale. The scale of each sub-factor is in the range of 0 to 100.

P = $\{P_1, P_2, P_3, ..., P_i, P_r\}$, when the number of subfactor is r.

Where

P_i is a sub-factor of parameter,

X_i is the value of the observation parameter data,

k is a total number of level in a context,

j is a level of observation data,

C_{i0} is the minimum value of the j^{th} level,

C_{ij} is the upper limit of the j^{th} level,

C_{ik} is the maximum value of level

In the case that a smaller value means better water-quality such as conductivity, total dissolved solid, the sub-factor value P_i is represented as below;

$$P_i = \begin{cases} 100 & \text{if } x < C_{i0} \\ \frac{100*(k-j)}{k} + \frac{100}{k} \cdot \frac{C_{ij}-X_i}{C_{ij}-C_{i(j-1)}} & \text{if} C_{i(j-1)} \leq x < C_{ij} \\ 0 & \text{if } x \geq C_{ik} \end{cases}$$

Where

Pi is a sub-factor of parameter,

X_i is the observation data,

k is a total number of level in a context,

j is a lever of observation data,

C_{i0} is the maximum value of the j^{th} level,

C_{ij} is the lower limit of the j^{th} level,

C_{ik} is the minimum limit of level

In the case that a bigger value means better water-quality such as dissolved oxygen, the sub-factor value P_i is represented as below;

$$Pi = \begin{cases} 100 & \text{if } x > C_{i0} \\ \frac{100*(k-j)}{k} + \frac{100}{k}\frac{X_i - C_{ij}}{C_{i(j-1)} - C_{ij}} & \text{if } C_{ij} < x \leq C_{i(j-1)} \\ 0 & \text{if } x \leq C_{ik} \end{cases}$$

Assigning weight to sub-factor

The weight of the assessment sub-factors are calculated based on their relative significance to overall water-quality.

Where

W_i is the weight of sub-factor value P_i,

q_i is a level of sub-factor value P_i

The method for calculating the weight of sub-factor is Eq. 3.9

$$W_i = \frac{q_i}{\sum_{i=1}^{r} q_i} \tag{3.9}$$

Calculating Factor' total value F

Where

F is a factor's total value for context, which is calculated as a summation of the sub-factor value P_i with weighting.

The method for calculating the total value F is represented as Eq. 3.10

$$F = \sum_{i=1}^{r} P_i Wi \tag{3.10}$$

Calculating threshold and classification

The classification of each factor in the context category is calculated based on the threshold value of each sub-class in the context category.

In each sub-class of the context calculated by using the factor calculation (Eq. 3.10) and sub-factor calculated from the lower limit of the sub-factor and the weight of the sub-factor. The classification of each factor in context is shown in Table 3.12

Table 3.12 The Calculating threshold and classification of context.

Context	level	Threshold classification	description
C_{x1}	I	$P \in \mathbb{R} \| P \leftarrow [87.5, 100]$	Excellent for agriculture
	II	$P \in \mathbb{R} \| P \leftarrow [75, 87.5)$	Hazard for sensitive crop
	III	$P \in \mathbb{R} \| P \leftarrow [62.5, 75)$	Hazard for low tolerance crop
	IV	$P \in \mathbb{R} \| P \leftarrow [50, 62.5)$	Hazard for high tolerance crop
	V	$P \in \mathbb{R} \| P \leftarrow [37.5, 50)$	Satisfactory for livestock
	VI	$P \in \mathbb{R} \| P \leftarrow [25, 37.5)$	Hazard for poultry
	VII	$P \in \mathbb{R} \| P \leftarrow [12.5, 25)$	Unfit for agriculture
	VIII	$P \in \mathbb{R} \| P \leftarrow [0, 12.5)$	Suddenly toxic for agriculture
C_{x2}	I	$P \in \mathbb{R} \| P \leftarrow [80, 100]$	Abundant for aquatic life
	II	$P \in \mathbb{R} \| P \leftarrow [60, 80)$	Support growth and activity for aquatic life
	III	$P \in \mathbb{R} \| P \leftarrow [40, 60)$	Support spawning
	IV	$P \in \mathbb{R} \| P \leftarrow [20, 40)$	Hazard for aquatic life
	V	$P \in \mathbb{R} \| P \leftarrow [0, 20)$	All aquatic life extinction
C_{x3}	I	$P \in \mathbb{R} \| P \leftarrow [66.66, 100]$	Optimum for drinking
	II	$P \in \mathbb{R} \| P \leftarrow [33.33, 66.66)$	Hazard and chronic toxic for drinking
	III	$P \in \mathbb{R} \| P \leftarrow [0, 33.33)$	Unfit and toxic for drinking
C_{x4}	I	$P \in \mathbb{R} \| P \leftarrow [80, 100)$	Abundant for fish
	II	$P \in \mathbb{R} \| P \leftarrow [60, 80)$	Optimum for fish and shrimp
	III	$P \in \mathbb{R} \| P \leftarrow [40, 60)$	Bacteria and plankton being disappear
	IV	$P \in \mathbb{R} \| P \leftarrow [20, 40)$	Hazard for fish and salmon dying
	V	$P \in \mathbb{R} \| P \leftarrow [0, 20)$	All fish extinction
C_{x5}	I	$P \in \mathbb{R} \| P \leftarrow [80, 100)$	Optimum for industrial process
	II	$P \in \mathbb{R} \| P \leftarrow [60, 80)$	Slightly corrosive scaling and fouling
	III	$P \in \mathbb{R} \| P \leftarrow [40, 60)$	Moderate corrosive scaling and fouling

Table 3.13 The Calculating threshold and classification of context ($Cont.$).

Context	level	Threshold classification	description
C_{x5}	IV	$P \in \mathbb{R} \mid P \leftarrow [20, 40)$	Highly corrosive scaling and fouling
	V	$P \in \mathbb{R} \mid P \leftarrow [0, 20)$	Unfit for industrial process
C_{x6}	I	$P \in \mathbb{R} \mid P \leftarrow [66.66, 100]$	Excellent for irrigation
	II	$P \in \mathbb{R} \mid P \leftarrow [33.33, 66.66)$	Moderate hazard for irrigation
	III	$P \in \mathbb{R} \mid P \leftarrow [0, 33.33)$	Hazard for irrigation
C_{x7}	I	$P \in \mathbb{R} \mid P \leftarrow [87.5, 100)$	Little risk of illness
	II	$P \in \mathbb{R} \mid P \leftarrow [74.5, 87.5)$	Moderately risk of illness
	III	$P \in \mathbb{R} \mid P \leftarrow [62.5, 74.5)$	Critical risk of illness
	IV	$P \in \mathbb{R} \mid P \leftarrow [48.9, 62.5)$	Strongly risk of illness
	V	$P \in \mathbb{R} \mid P \leftarrow [0, 48.9)$	Excessively risk of illness

Time-series data structure

After the observation data are represented in the form of time series, the system orders the results by descending order in multiple contexts, to show a time-series environmental change. The set of time-series total value F is described as

$\{F_{t-1}, F_t, \ldots, F_\infty\}$

The example of calculation for Water-quality Factor

In this subsection, we represent the example of calculation for Water-quality Factor as below;

Where

Context is an agriculture context.

Pi is a sub-factor of parameter,

X_{i-cond} is the observation data of conductivity parameter. In this case X_{i-cond} = 25214.29,

X_{i-tds} is the observation data of total dissolved solid parameter. In this case X_{i-tds} = 1624.29,

X_{i-sal} is the observation data of salinity parameter. In this case X_{i-sal} = 15.379,

k is a total number of level in a context, in this case k = 8,

j is a lever of observation data. In this case j_{cond} = 8, j_{tds} = 4, and j_{sal} = 8,

q_i is a level of subfactor value P_i. In this case q_{i-cond} = 8, q_{i-tds} = 4, q_{i-sal} = 8,

C_{i0} is the minimum value of j^{th} level. In this case $C_{i0-cond}$ = 0, C_{i0-tds} = 0, C_{i0-sal} = 0,

C_{ij} is the upper limit of the j^{th} level. In this case $C_{ij-cond}$ = 100000, C_{ij-tds} = 3200, C_{ij-sal} = 100,

C_{i-j} is the upper limit of the j^{th} level. In this case $C_{i-j-cond}$ = 16000, $C_{i-j-tds}$ = 1500, $C_{i-j-sal}$ = 10,

C_{ik} is the maximum limit of level. In this case $C_{ik-cond}$ = 100000, C_{ik-tds} = 20000, C_{ik-sal} = 100

Calculate Pi

From $Pi = \frac{100\times(k-j)}{k} + \frac{100}{k} \times \frac{C_{ij}-X_i}{C_{ij}-C_{i(j-1)}}$

$$Pi_{cond} = \frac{100\times(8-8)}{8} + \frac{100}{8} \times \frac{100000-25214.29}{100000-16000}$$
$$Pi_{cond} = 11.13$$
$$Pi_{tds} = \frac{100\times(8-4)}{8} + \frac{100}{8} \times \frac{3200-1624.29}{3200-1500}$$
$$Pi_{tds} = 61.59$$
$$Pi_{sal} = \frac{100\times(8-8)}{8} + \frac{100}{8} \times \frac{100-15.379}{100-10}$$
$$Pi_{sal} = 11.75$$

Calculate W_i

From $W_i = \frac{q_i}{\sum_{i=1}^{r} q_i}$

$$W_{i-cond} = \frac{8}{20}$$
$$W_{i-cond} = 0.4$$
$$W_{i-tds} = \frac{4}{20}$$
$$W_{i-tds} = 0.2$$
$$W_{i-sal} = \frac{8}{20}$$
$$W_{i-sal} = 0.4$$

Calculate Factor' total value F

From $F = \sum_{i=1}^{r} P_i Wi$

$$F = (Pi_{cond} \times W_{i-cond}) + (Pi_{tds} \times W_{i-tds}) + (Pi_{sal} \times W_{i-sal})$$
$$F = (11.13 \times 0.4) + (61.59 \times 0.2) + (11.75 \times 0.4)$$
$$F = 22.65$$

From the F = 22.65, the meaning is "Unfit for agriculture"

Chapter 4

Implementation

This chapter describes the system design and gives an overview of the proposed water-quality analysis system. The concept of multi-dimensional space is included in processing and analyzing parts of the system architecture for interpretation of the water-quality situation. The new innovative idea is to integrate specialist knowledge on water quality issues with semantic computing based on MMM by reform its core to dealt with the complexity of environmental situation interpretation, in this case is Water Quality Interpretation. The main groundworks are (1) To realize and create the knowledge interpretation from the context database within the professional level water-quality analysis field, (2) To create the semantic space from the dynamic dimensions of river water-quality interpretation, and (3) To create the semantic space parameter relatedness weighting method for diverse river water-quality variability. These are transformed into a new way of knowledge interpretation on water quality. The invented idea is built to given an uncomplicated message in environmental scientific terms for public consideration. The main feature in this dissertation is semantic analysis using as, an essential base, human-language interpretation in water quality. The crucial system explanation is to illustrate the meta-level knowledge in the database system for environmental engineering field in water resources and rivers. Knowledge integration with specialists and environmental issues creates the dimension subspace and heavy metal process for the river water-quality parameter.

4.1 System design

For the system architecture shown in Figure 4.1,The Water-quality Analysis System with Multi-Dimensional Spaces for Interpreting Environmental Situations is outlined as follows: (1) The green box is shown to input data sources such as observation data and open data or request data. (2) The purple box is shown as the processing and analysis parts. (3) The blue box is shown as output or results in an actuation. The system architecture is shown in Figure 4.1

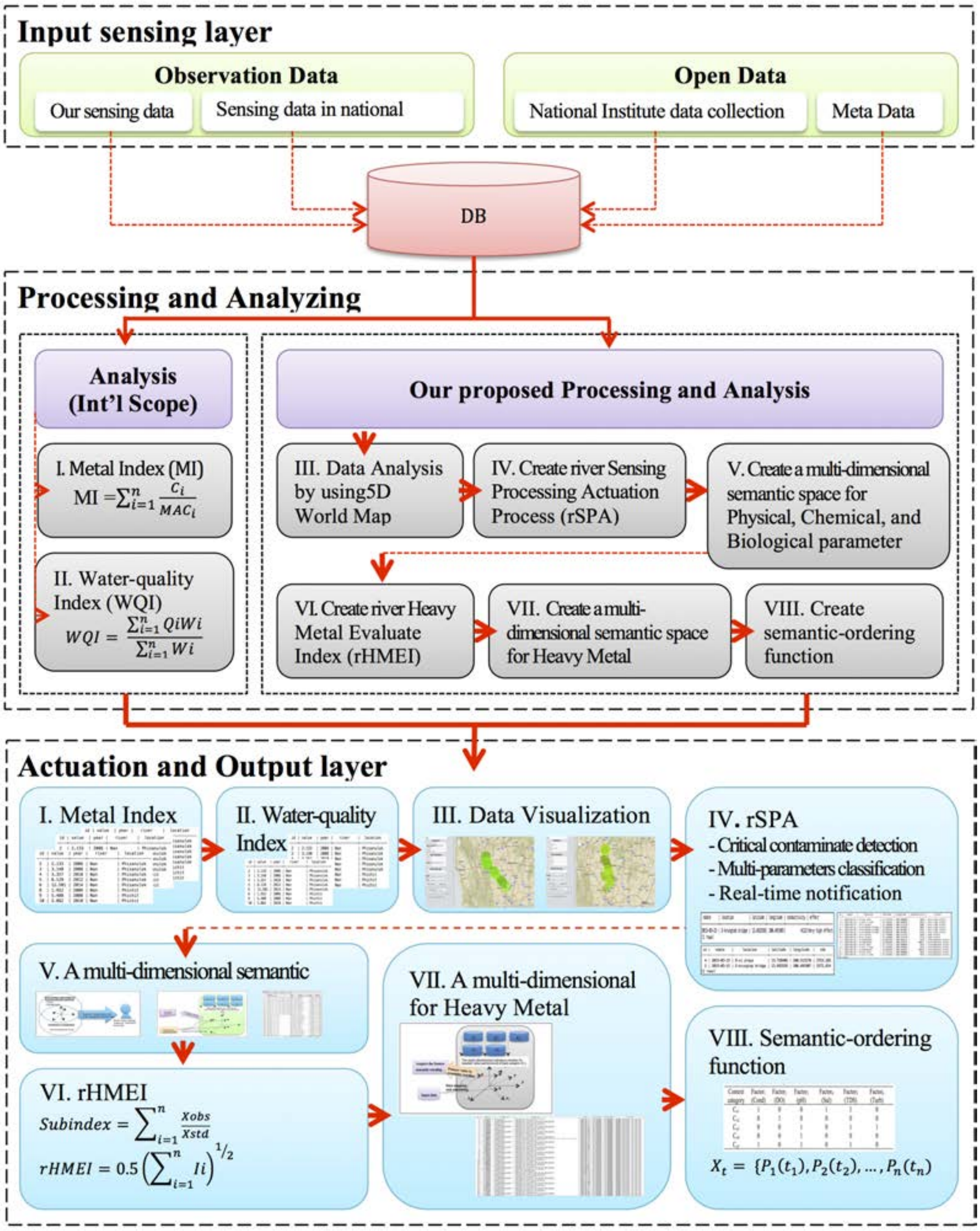


Fig. 4.1 The System Architecture.

This system process illustrates the meta-level knowledge to integrate the knowledge specialists with various environmental issues, and semantic computing. This can create the dimensional subspace of river water-quality parameters.

The system design is comprised of the processing and analysis processes, which are separated into 3 main parts (1) creating data structure and utilizing indicators in the database for water-quality analysis by using the index and rSPA processes, (2) creating the data structure and multidimensional spaces in the database for water-quality analysis by using semantic subspace and semantic-ordering function, and (3) creating the river Heavy Metal Evaluate Index (rHMEI) and multidimensional space of heavy metal parameters in the database for water-quality analysis by using mathematical calculations and the semantic subspace.

In the first part, there are 2 procedures (1) calculating and determining of the level of water quality and metal concentration in the river by using the mathematical tools to transform the large quantities of water-quality data into a single number based on international standard values, and (2) creating a rSPA base of SPA processes, which is a tool for detection of the critical points, classification of multi-parameters in detail and actuation of critical contaminate detection, classification of multiple-parameter waters by a real-time warning system based on a trigger. In the real-time warning system, the system automatically searches, calculation data are sent to the warning action (including spatio-temporal data). The database architecture for processing and analysis of part 1 is shown in Figure 4.2 The process design for analyzing is shown in algorithms 1 and 2 (Chapter 3.2).

In the second part, there are 2 procedures: (1) Creating the database of water pollutant variables and multi-dimensional semantic space. (2) Creating the semantic ordering function.

- In the first procedure, the system automatically selects the parameter that relates to the target group, the semantic space creation maps input data and executes semantic wording to the user. The process is designed for analyzing, it is shown in algorithm 3 (Chapter 3.3). The main procedures for creating the multi-dimensional space is via the following steps:
  Step 1: The creation of the category target by multi-water-parameters and feature wording, chronic-sudden toxic class in database.
  Step 2: The process selects the multi-water-quality parameters that relate to the target group (select by user), and creates the multi-dimensional semantic space.
  Step 3: The process of mapping the input data. In this step, the process maps input data into the multi-dimensional semantic space.
  Step 4: The process executes feature word processing by selecting the

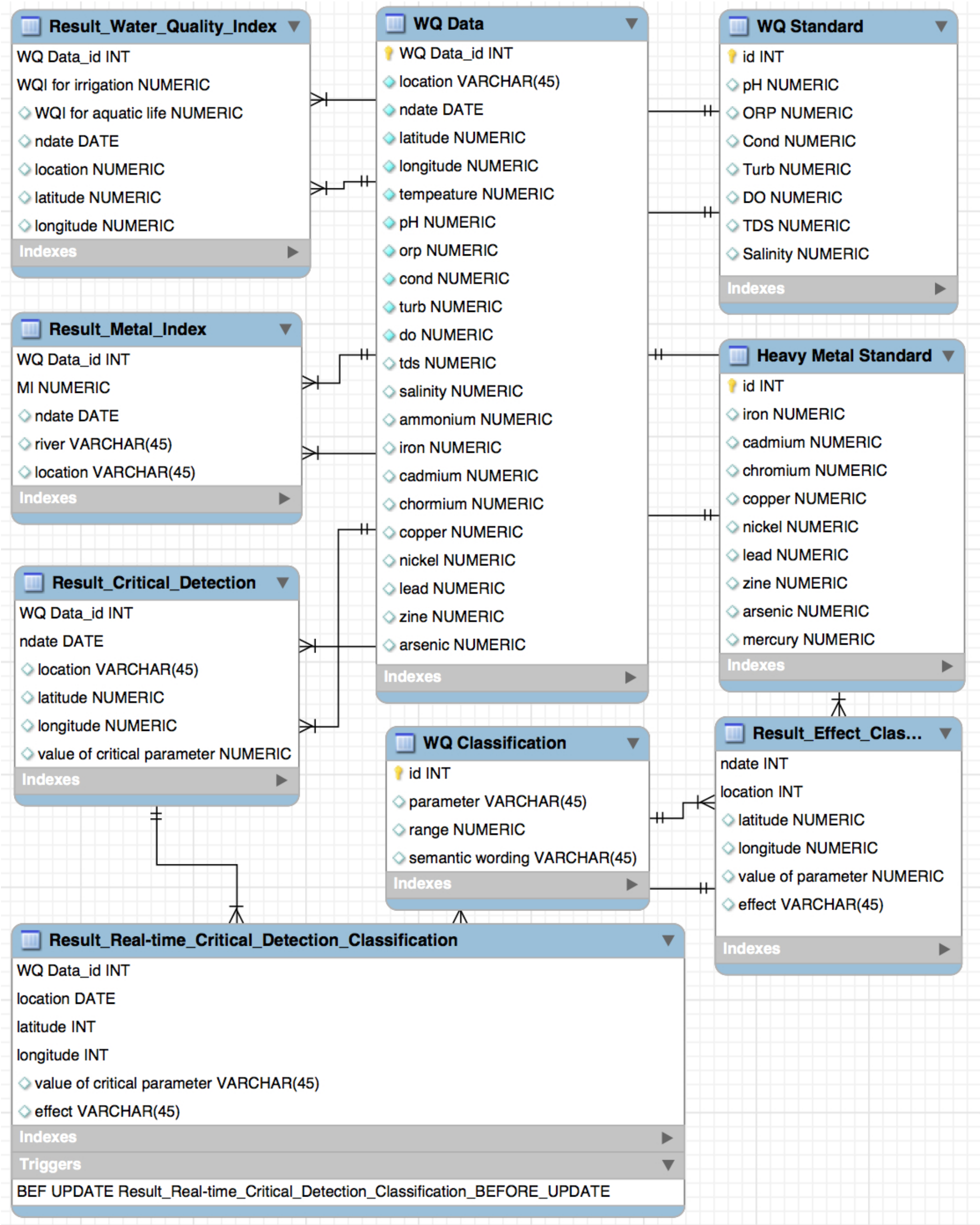


Fig. 4.2 The database architects for processing and analysis (part 1).

important word in the water-quality parameter field range.

- In the second procedure, the system automatically analyses a single parameter and multi-parameter base using the designed algorithms 1 and 2 (Chapter 3.5), then executes the feature word (including spatio-temporal data) and water-quality order ranking. The step for creating the database of the single-multi water-quality parameters and water-quality analysis system with semantic-ordering functions is as follows:
  Step 1: The process of database creation. This process creates multiple water-quality database.
  Step 2: The process of creation of semantic context for the automatic human-interpreting system. The process establishes the professional knowledge level databases in water-quality analysis.
  Step 3: The process of semantic space creation. This process proposes dynamic-dimensions for river-water-quality interpretation for analyzed spatial-dynamics environmental changes in multiple contexts.
  Step 4: The process of mapping input data. This process maps the spatial global water-quality data into the multi-dimensional space.
  Step 5: The process of semantic space parameter-relatedness weighting method of diverse river-water-quality variability. This process creates the mathematic formula for semantic-ordering functions.
  Step 6: The process of water-quality analysis with semantic-ordering functions on a single parameter. This process computes the ordering of single parameters and executes feature word and ranking for the spatial dynamics water-quality data into a single parameter.
  Step 7: The process of water-quality analysis with semantic-ordering functions on a multiple parameters. This process computes multiple parameters and executes the feature word and ranking for the spatial dynamics water-quality data on a multi parameter space.

The database architects for processing and analysis of part 2 is shown in Figure 4.3.

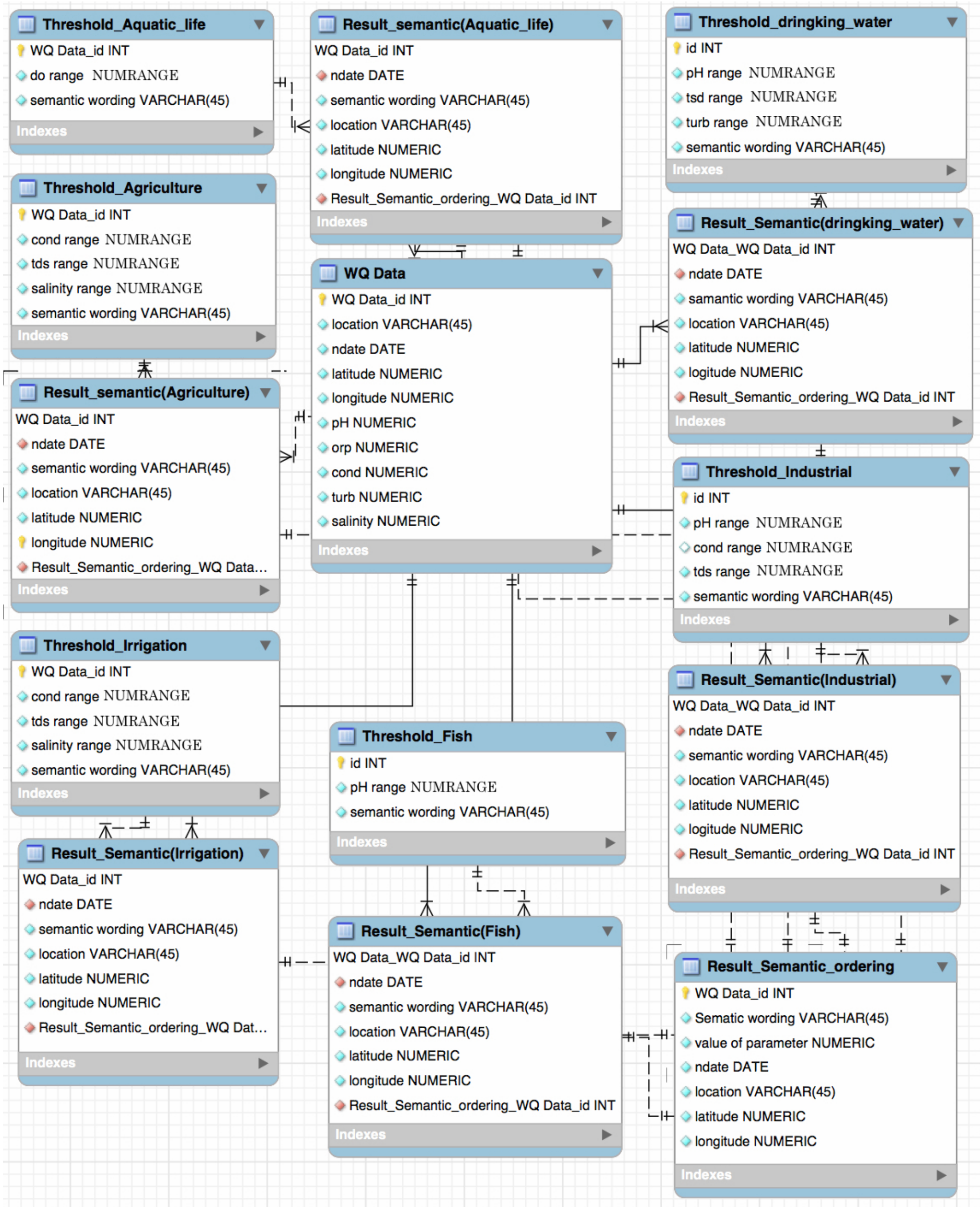


Fig. 4.3 The database architects for processing and analysis (part 2).

In the third part, there are 2 procedures: (1) Creating the river Heavy Metal Evaluate Index (rHMEI). (2) Creating the database and multi-dimensional semantic space for heavy metal parameters.

- In the first procedure, the system creates a database of heavy metals and a threshold value in several contexts.
- In the second procedure, the system automatically creates the multi-dimensional semantic space for heavy metal parameters, computing the rHMEI value, and detecting a critical situation by the use of standard threshold values in each context.

The results of the feature wording as an actuation on rSPA executes feature word processing by detecting the rHMEI value in the parameters heavy metal level of each category (including spatio-temporal data). The database architecture for processing and analysis of part 3 is shown in Figure 4.4.

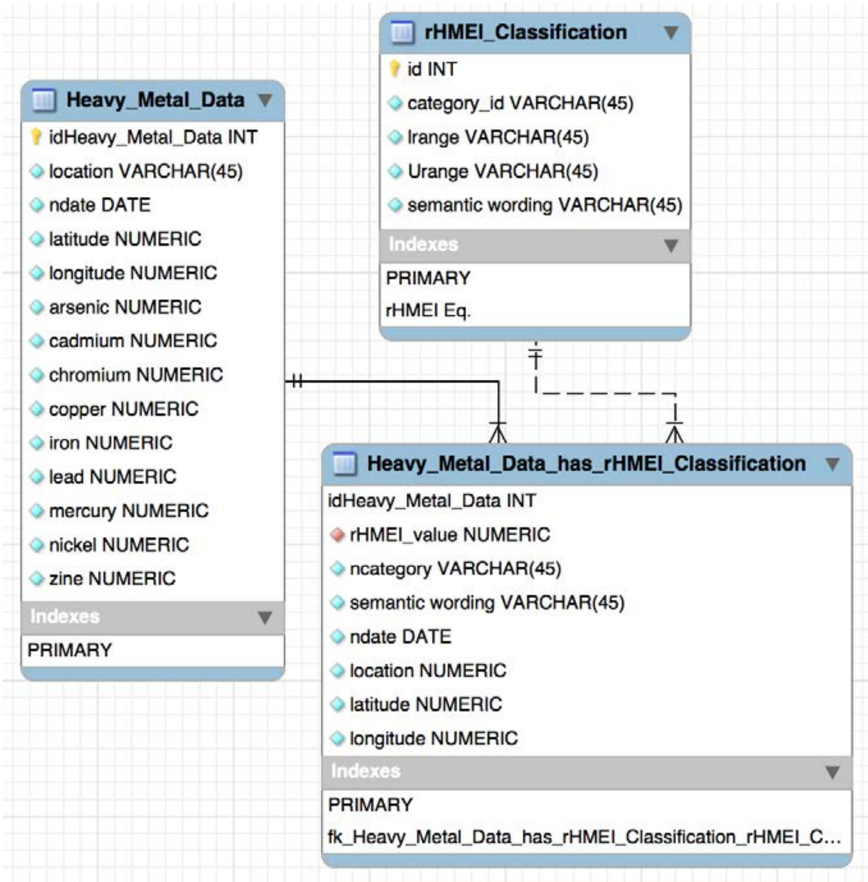


Fig. 4.4 The database architects for processing and analysis (part 3).

4.2 Data Structure

In this section, this dissertation describes water-quality data from the input sensing part. Water-quality data in this system consists of 2 parts as follows:

- Observation data which are data from our sensor and data from the national sensor.
- Open data and historical data, which are data from national institutes, meta-data, and requested data.

Then this dissertation creates the water-quality database for the 5D World Map system and semantic space. The data structure of the 5D World Map system and semantic space are shown in subsection below

4.2.1 Data Structure on 5D World Map System

In this subsection, this research collected water-quality data (Physical, Chemical, Biological, and Heavy Metal parameters) from Thailand, Surabaya (Indonesia), Hawaii (USA), Pori (Finland), Riga (Latvia), and Vientiane (Lao People's Democratic Republic, Laos). After that, the researcher prepared data files in CSV form (28 parameters from 36 rivers) and added semantic and spatio-temporal meta-data, such as Category, Location, Date, and Description of the study area. The data structures of this section are based on data structures of the 5D World Map System, which are shown in Figure 4.5. Following the data structure on the 5D World Map system, each water-quality parameter is created and stored in separate tables on the 5D World Map system database. The schema of the tables is id (data id), value (value of parameter or attribute), date (YYYY/MM/DD), location (name of location), latitude (lat coordinate), longitude (long coordinate). A meta-data of water-quality is mapped onto the semantic space on the 5D World Map system. The study visualizes the numerical and actual data with spatio-temporal meta-data. As a result of the function, this research analyzed and visualized the water-quality situation, including contamination and polluted areas, by comparison of places, time, and time-series as a set of colored polygon data or variable-sized markers.

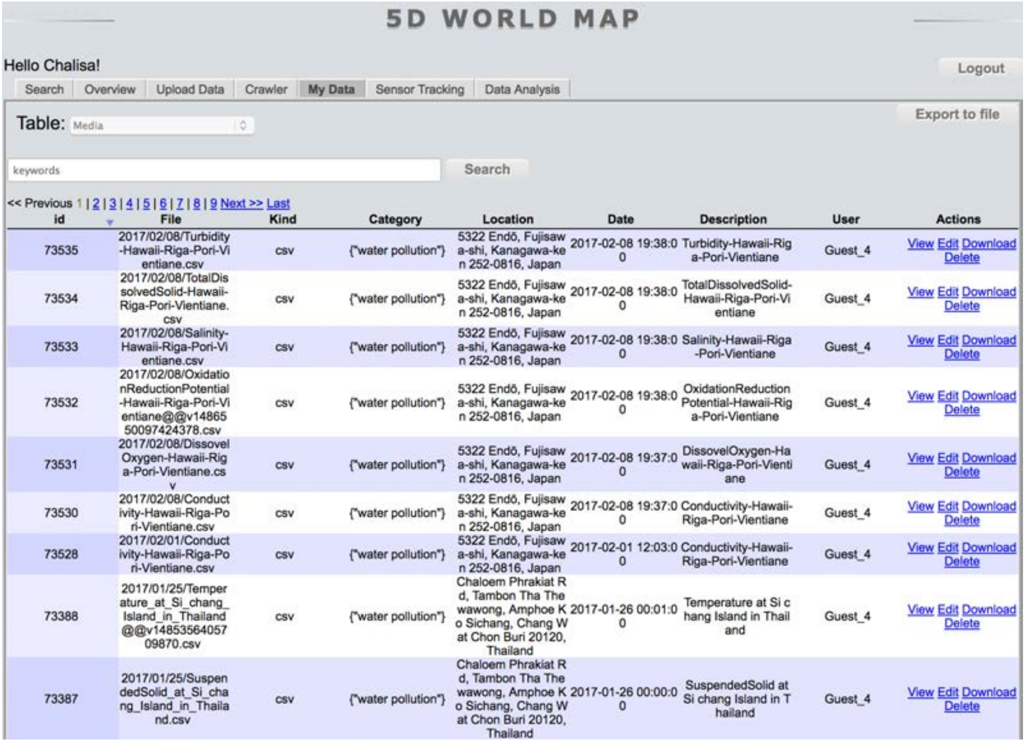


Fig. 4.5 The data structures on 5D World Map System.

4.2.2 Data Structure on the database for semantic space

In this subsection, this research describes the database stored water-quality for the semantic space and the same using the water-quality data from the previous subsection. Also, every water-quality database contains the specific name of the parameter. The data schema is designed and created in the database. A data skimmer is a collection of related data, which can be defined in a structured format database.

A data schema of a raw data table consists of (1) columns of id, date, location, latitude, longitude and water parameters, and (2) rows of a set of data or identified id of each column.

A data schema of the classification table consists of (1) columns of id, the threshold value of parameters, effect, and semantic wording, and (2) rows set of classes followed or identified id of each column. The database schema design for water-quality in the part of the physical-chemical parameters and heavy metals in this thesis are shown in Figures 4.6 and 4.7.

id	location	ndate	ntime	latitude	longitude	temperature	ph	orp	conductivity	turbidity	dissolvedoxygen	tds	salinity	depth
1	Kokemaenjoki-1	2016-05-26	10:04:11	61.493724	21.827543	16.92	7.7	245	0.098	73.7	10.21	0.064	0	0
2	Kokemaenjoki-0	2016-05-26	10:59:16	61.491764	21.836955	16.19	6.06	371	0.091	13.4	8.27	0.059	0	1.55
3	Kokemaenjoki-2	2016-05-26	12:01:02	61.492561	21.810844	16.27	6.22	388	0.082	3.32	7.98	0.054	0	0.4
4	Kokemaenjoki-3	2016-05-26	12:29:03	61.491749	21.802233	16.3	6.19	395	0.089	3.15	7.7	0.058	0	0.4
5	Kokemaenjoki-4	2016-05-26	14:24:24	61.493241	21.794315	17.13	6.65	359	0.091	57.9	8.82	0.059	0	0.3
6	Kokemaenjoki-5	2016-05-26	14:58:21	61.496476	21.789177	16.1	6.31	358	0.113	10.6	8	0.074	0.1	0.4
7	Kokemaenjoki-6	2016-05-26	15:34:32	61.498451	21.783281	15.97	6.54	352	0.082	4.01	7.95	0.054	0	0.1
8	Kokemaenjoki-7	2016-05-26	16:19:22	61.490174	21.786602	15.98	6.28	372	0.088	20.3	7.67	0.057	0	0.4
9	Kokemaenjoki-0	2016-05-30	10:15:42	61.491764	21.836955	18.8	7.03	260	0.137	9.9	7.68	0.089	0.1	0.5
10	Kokemaenjoki-1	2016-05-30	10:46:12	61.493724	21.827543	18.14	6.82	298	0.097	0	6.54	0.063	0	0.25
11	Kokemaenjoki-2	2016-05-30	11:32:01	61.492561	21.810844	17.52	6.18	343	0.098	5.89	6.46	0.064	0	1
12	Kokemaenjoki-3	2016-05-30	11:54:42	61.491749	21.802233	17.33	6.21	369	0.093	3.27	6.31	0.061	0	0.95
13	Kokemaenjoki-4	2016-05-30	12:22:21	61.493241	21.794315	17.19	6.36	260	0.091	22.4	6.6	0.059	0	0.25
14	Kokemaenjoki-5	2016-05-30	12:51:11	61.496476	21.789177	17.2	6.08	341	0.094	5.26	7.05	0.061	0	1.05
15	Kokemaenjoki-6	2016-05-30	13:19:53	61.498451	21.783281	17.3	6.51	321	0.061	4.67	10.67	0.039	0	0.45
16	Kokemaenjoki-7	2016-05-30	13:54:12	61.490174	21.786602	17.67	6.3	363	0.098	45	8.19	0.064	0	0.85
17	DAUGAVA	2016-06-02	11:26:01	56.91432	24.167056	23.55	7.86	222	0.269	0.1	7.71	0.175	0.1	0.2
18	DAUGAVA2	2016-06-02	11:48:01	56.913257	56.913257	23.05	7.41	269	0.277	0	9.44	0.18	0.1	0.55
19	DAUGAVA3	2016-06-02	12:26:51	56.937328	24.114188	20.51	7.27	254	0.27	6.22	9.53	0.175	0.1	0.65
20	LIELUPE	2016-06-02	15:52:42	56.973468	23.861143	26.09	8.19	173	0.829	4.6	8.51	0.53	0.4	0.15
21	BALTIK SEABAY	2016-06-02	16:50:23	56.978994	23.806943	24.08	8.51	204	9.01	0	8.36	5.68	5	0.2
22	Pljavnieki tabwater	2016-06-03	10:52:09	0	0	27.34	6.18	201	0.238	102	6.87	0.155	0.1	0.05
24	Pljavnieki tabwater	2016-06-03	20:05:31	0	0	27.49	6.28	129	0.134	109	6.68	0.087	0.1	0.05
25	Garden underground	2016-06-03	20:17:41	0	0	27.82	11.12	73	0.046	2.52	5.2	0.03	0	0.1
26	Kokemaenjoki-0	2016-06-13	8:49:52	61.491764	21.836955	17.17	7.17	167	0.096	12.2	10.61	0.062	0	0.8
27	Kokemaenjoki-1	2016-06-13	10:33:01	61.493724	21.827543	18.36	7.59	200	0.097	8.95	12.77	0.063	0	0.15
28	Kokemaenjoki-2	2016-06-13	10:48:11	61.492561	21.810844	18	7.35	256	0.094	469	9.09	0.061	0	0.3
29	Kokemaenjoki-3	2016-06-13	11:09:01	61.491749	21.802233	18.02	7.32	233	0.096	445	11.67	0.063	0	0.15
30	Kokemaenjoki-4	2016-06-13	11:31:21	61.493241	21.794315	17.53	7.31	271	0.097	5.59	9.66	0.063	0	0.3
31	Kokemaenjoki-5	2016-06-13	12:01:11	61.496476	21.789177	17.89	7.3	245	0.098	6.77	10.39	0.064	0	0.05
32	Kokemaenjoki-6	2016-06-13	12:25:11	61.498451	21.783281	18.98	7.43	254	0.098	6.96	11.27	0.063	0	0.35
33	Kokemaenjoki-7	2016-06-13	13:09:42	61.490174	21.786602	17.92	6.71	302	0.1	4.42	11.09	0.065	0	0.25
34	Kokemaenjoki-0	2016-06-19	9:13:11	61.491764	21.836955	17.32	7.9	121	0.101	6.41	11.15	0.065	0	0.2
35	Kokemaenjoki-1	2016-06-19	9:54:11	61.493724	21.827543	17.11	11.23	-19	0	15.2	11.28	0	0	0
36	Kokemaenjoki-2	2016-06-19	10:29:01	61.492561	21.810844	16.8	7.51	235	0.096	6.33	9.74	0.063	0	0.05
37	Kokemaenjoki-3	2016-06-19	10:48:51	61.491749	21.802233	16.75	6.69	276	0.095	11	9.68	0.062	0	0.35
38	Kokemaenjoki-4	2016-06-19	11:10:21	61.493241	21.794315	16.8	7.21	257	0.097	27.2	11.22	0.063	0	0.05

Fig. 4.6 The database schema design for water-quality in part of physical and chemical parameters.

id	ar	cd	cr	cu	fe	pb	ni	zn	hg	ndate	location	latitude	longitude
1	0.720	0.040	1.200	2.400	1800.000	0.450	4.500	7.900	0.000	2013-01-07	66209::Eteljoki tie 272 mts	61.646590	21.689960
2	0.750	0.020	1.100	2.300	1900.000	0.400	4.100	5.600	0.000	2013-02-12	66209::Eteljoki tie 272 mts	61.646590	21.689960
3	0.710	0.020	0.800	2.100	2600.000	0.480	3.400	10.000	0.000	2013-03-12	66209::Eteljoki tie 272 mts	61.646590	21.689960
4	0.730	0.050	0.870	2.000	2100.000	0.900	4.900	6.500	0.000	2013-04-09	66209::Eteljoki tie 272 mts	61.646590	21.689960
5	1.200	0.060	1.500	2.800	4500.000	1.500	3.500	15.000	0.000	2013-04-18	66209::Eteljoki tie 272 mts	61.646590	21.689960
6	1.000	0.047	3.700	3.500	2700.000	1.000	4.400	11.000	0.000	2013-04-25	66209::Eteljoki tie 272 mts	61.646590	21.689960
7	0.820	0.034	0.920	1.800	1600.000	0.720	3.500	12.000	0.000	2013-05-06	66209::Eteljoki tie 272 mts	61.646590	21.689960
8	0.740	0.031	1.200	2.800	1600.000	0.660	3.600	5.000	0.000	2013-05-21	66209::Eteljoki tie 272 mts	61.646590	21.689960
9	1.100	0.016	1.000	1.300	1300.000	0.340	2.100	2.900	0.000	2013-06-13	66209::Eteljoki tie 272 mts	61.646590	21.689960
10	1.200	0.011	0.420	1.300	1800.000	0.530	1.100	1.400	0.000	2013-07-22	66209::Eteljoki tie 272 mts	61.646590	21.689960
11	0.980	0.010	0.360	1.400	1500.000	0.450	2.500	1.500	0.000	2013-08-07	66209::Eteljoki tie 272 mts	61.646590	21.689960
12	0.820	0.015	0.380	1.300	1100.000	0.310	1.800	1.200	0.000	2013-09-18	66209::Eteljoki tie 272 mts	61.646590	21.689960
13	0.740	0.047	0.700	2.000	1400.000	0.450	4.700	0.000	0.000	2013-11-18	66209::Eteljoki tie 272 mts	61.646590	21.689960
14	0.730	0.056	0.840	2.000	1500.000	0.960	4.300	11.000	0.000	2014-01-08	66209::Eteljoki tie 272 mts	61.646590	21.689960
15	0.700	0.051	0.760	1.700	1700.000	0.850	4.500	9.000	0.000	2014-02-11	66209::Eteljoki tie 272 mts	61.646590	21.689960
16	0.650	0.040	1.000	1.700	1300.000	0.370	4.500	9.800	0.000	2014-03-04	66209::Eteljoki tie 272 mts	61.646590	21.689960
17	0.650	0.027	0.850	2.100	1400.000	0.370	4.200	11.000	0.000	2014-03-31	66209::Eteljoki tie 272 mts	61.646590	21.689960
18	0.640	0.025	1.100	1.500	1300.000	0.470	5.100	6.900	0.000	2014-04-08	66209::Eteljoki tie 272 mts	61.646590	21.689960
19	0.700	0.037	1.600	1.700	1800.000	0.790	4.400	8.800	0.000	2014-04-15	66209::Eteljoki tie 272 mts	61.646590	21.689960
20	0.750	0.025	1.000	8.000	1300.000	0.760	4.000	4.700	0.000	2014-05-13	66209::Eteljoki tie 272 mts	61.646590	21.689960
21	0.780	0.070	1.000	1.400	1200.000	1.500	3.800	6.600	0.000	2014-06-09	66209::Eteljoki tie 272 mts	61.646590	21.689960
22	1.400	0.010	1.000	1.500	1700.000	0.440	2.600	1.600	0.000	2014-08-11	66209::Eteljoki tie 272 mts	61.646590	21.689960
23	0.630	0.010	0.360	1.200	1200.000	0.370	2.100	2.200	0.000	2014-09-29	66209::Eteljoki tie 272 mts	61.646590	21.689960
24	0.610	0.013	1.000	0.900	1200.000	0.230	2.400	0.000	0.000	2014-10-20	66209::Eteljoki tie 272 mts	61.646590	21.689960
25	0.000	0.010	0.000	0.190	1.600	0.000	13.000	2.000	0.230	2014-07-29	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
26	0.000	0.010	0.000	0.220	1.500	0.000	7.900	1.700	0.100	2014-08-06	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
27	0.000	0.010	0.000	0.320	2.000	0.000	7.600	2.500	0.610	2014-08-13	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
28	0.000	0.010	0.000	0.280	1.500	0.000	6.400	2.700	0.670	2014-08-19	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
29	0.000	0.010	0.000	0.180	1.300	0.000	5.700	0.740	0.290	2014-08-27	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
30	0.000	0.010	0.000	0.320	1.900	0.000	5.600	2.400	0.410	2014-09-10	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
31	0.000	0.010	0.000	0.370	2.000	0.000	5.300	9.100	0.360	2014-10-13	6451::Kojo 37 Varvoorinjuopa	61.482560	21.851450
32	0.000	0.040	0.000	4.000	1600.000	0.000	6.100	9.300	0.005	2013-01-08	6458::Kojo 46 Isojuopa	61.546880	21.715920
33	0.000	0.030	0.000	1.600	500.000	0.000	3.000	3.400	0.005	2013-03-11	6458::Kojo 46 Isojuopa	61.546880	21.715920
34	0.000	0.030	0.000	2.200	1100.000	0.000	3.600	5.900	0.005	2013-05-20	6458::Kojo 46 Isojuopa	61.546880	21.715920
35	0.000	0.080	0.000	2.900	880.000	0.000	5.700	5.200	0.005	2013-06-03	6458::Kojo 46 Isojuopa	61.546880	21.715920

Fig. 4.7 The database schema design for water-quality in part of heavy metal parameter.

Chapter 5

Data Preparation

This chapter describes the data preparation. To realize the water-quality analysis system, the representative data were required for creating database on the 5D World Map system and for expressing the data structure of the multi-dimensional semantic space. There were two terms for the data used in this study: open data (historical data) and observation data. The historical data represented past events and circumstances pertaining to water resources in terms of the time line. The sampling data were independently gathered data from research monitoring, which were presented to the current situation. These data types were specified to interpret the environmental situation. This chapter presented the process and source of collecting the data and the sampling data.

5.1 Data collection

The data collection process was water-quality data collection for sensing phase (S), the first phase of this system. The data were raw water-quality input data obtained by water sensing equipment for collecting data in the study areas. By all means, the goal in this process was to gather sensing-value information for implantation into the proposed method and to interpret the water-quality situation.

5.1.1 Thailand

Data Source

The collected historical data of water quality were monitored data from the Pollution Control Department, Ministry of Natural Resource and Environment (Thailand) [60]. The water quality data were collected from 2004 to 2014. The collection of historical data and their sources are shown in Table 5.1.

The Department of Pollution Control, Ministry of Natural Resource and Environment was established on June 4, 1992, under the Ministry of Science, Technology and Environment B.E. 2535 (1992), in addition to the enhancement and conversation of the National Environment Quality Act B.E. 2535 (1992). The Department of Pollution Control is an organization for trust and confidence in the management of pollution for a better environment and better quality of life.

Table 5.1 The collection of historical data and their sources.

Type of Data	Sources of Data
Review Document	Review on Journals and textbook
Water-quality Data	Pollution Control Department, Thailand
GIS Data: Latitude, Longitude	http://www.pcd.go.th, http://maps.google.com

Description of study area

The study areas of water quality were in the rivers of Thailand such as Ping, Wang, Yom, Nan, Kuang, Kok, Kwan Phrayao, Mae Jang, Ing, Chee, Mun, Lamtakhon, Loei, Rayong, Welu, Chao Phraya, Kheaw Yai, Kheaw Noi, Kui Bure, Petchabun, Thajen, Pha Sak, Chumporn, Pattane, and Trang river. The description of the data sampling points from the Pollution Control Department, Thailand is shown in Table 5.2.

5.1.2 Pori, Finland

The collected water quality data in this study were obtained from Open Data form (Open Knowledge Foundation, 2016) for surface water quality provided by the Finnish Environment Institute SYKE (SYKE, 2016) [61]. In 2015, the dataset contained over 2.7 million water samples and 28 million analysis results from almost 70,000 locations all over Finland. For this study, we focused on sampling points that were located in the municipality of Pori. The population of Pori is 85,000 civilians. The city of Pori is located on the west coast of Finland on the estuary of the Kokemäenjoki river, about 15 kilometers from the Gulf of Bothnia. The description of the data points from the Finnish Environment Institute is shown in Table 5.3.

Table 5.2 Description of the data collection for rives in Thailand.

River	Areas(sq.km)	Latitude	Longitude
Ping	12,426.20	5.720039-19.453152	100.144566-98.99523
Wang	6,860.50	17.136486-18.695487	99.104920-99.569321
Yom	15,283.65	15.912479-16.799990	100.25069-100.28512
Nan	17,809.81	15.652099-19.125264	100.14493-100.81062
Kuang	2,876.70	18.541809-18.964389	98.940019-99.237288
Kok	2,055.09	19.919988-20.227243	99.846032-100.12879
Kwan Phrayao	N/A	19.157037-19.166234	99.917641-99.897902
Mae Jang	1,196.62	18.114083-18.163942	99.413816-99.659983
Ing	3,105.72	19.832829-20.136734	100.20013-100.42028
Chee	17,433.03	15.180476-16.250521	98.719076-97.072446
Mun	69,700.44	14.561359-15.432204	96.175253-97.015786
Lamtakhon	3,310.64	14.636499-15.019828	101.42214-101.72879
Loei	N/A	17.492023-17.858344	101.73752-101.61446
Rayong	N/A	12.656131-12.847320	101.28099-101.30407
Welu	N/A	12.335528-12.458591	102.26598-102.31289
Chao Phraya	15,875.14	5.510661-6.008650	110.07648-108.03259
Kheaw Yai	9091.68	14.022690-14.399515	99.526127-99.138532
Kheaw Noi	7,498.92	14.014146-14.891130	99.525857-98.520744
Kui Bure	N/A	12.039423-12.059113	99.909704-99.859663
Petchabun	5,132.15	12.813409-13.223570	99.794241-99.990462
Thajen	11,561.78	13.510005-15.209973	100.27485-100.07426
Pha Sak	12,432.86	14.349358-16.648211	100.58469-101.21680
Chumporn	N/A	10.439674-10.576708	100.14109-99.250837
Pattane	3,654.87	6.134718-6.895482	101.27478-101.25358
Thrang	3,449.27	7.313309-7.9420199	99.507822-99.581391

Table 5.3 Description of the data collection for rives in Pori, Finland.

Sampling points	Latitude	Longitude
Eteläjoki tie 272	61.64659	21.68996
Kojo 37 Varvoorinjuopa	61.48256	21.85145
Kojo 46 Isojuopa	61.54688	21.71592
Metsä-Ahla allas MA1	61.63602	21.63688
Pome 119 Iso-Ensk luot	61.70105	21.34225
Pome 235 Säppi koill	61.50524	21.37808
Pome 260 Mkallo 4 mpk lo	61.57857	21.31642
Pome 270 Reposaari lä	61.61858	21.39974
Pome 276 Hylkiriutta lo	61.63525	21.27138
Pome 50 Pussaanluoto	61.56925	21.63852
Pome 51 Sådösaar et	61.58369	21.60059
Pome 56 Kolppa	61.60155	21.55666
Pome 58 eteläselkä	61.61230	21.46563
Pome 64 Lannask koill	61.63422	21.55499
Pome 67 Tahkol luot	61.64261	21.38593
Pome 70 Kristisk lä	61.65742	21.56636
Pome 71 Arvenk pohj	61.66005	21.40482
Pome 72 Iso-Väkk lä	61.66861	21.47688
Pome 83 Isot Plokit lä	61.72599	21.44163
Pome 86 Yyterin ed	61.55881	21.49494
Pome 88 Kolmikulma	61.59592	21.45334
Rahkakeitaan kp kaiv 10	61.66603	22.51338
Rahkakeitaan kp oja itä	61.66722	22.50495

5.2 Data sampling

In this stage, sampling water-quality data from significant water resources located in Bangkok (Thailand), Surabaya (Indonesia), Hawaii (USA), Pori (Finland), Riga (Latvia), and Vientiane (Laos) from February 2015 to September 2016 with multi water parameter sensors were used. By using the water parameter measurement consisting of Temperature, pH, Dissolved Oxygen (DO), Conductivity, Salinity, Total Dissolved Solid, Turbidity, Oxidation-Reduction Potential (ORP), and GPS, the process of water quality sampling proceeded according to the standardization of ISO 5667-6 [42]. The geographic location and the sampling points of data fare is shown in Figures 5.1-5.6.

5.2.1 Water-quality monitoring

The water samples were collected from different places to determine the level of pollution of the water resources. The process of sampling the water follows the standard of ISO 5667-6 [42]. The water parameters consisted of Temperature, pH, Dissolved Oxygen (DO), Conductivity, Salinity, Total Dissolved Solid, Turbidity, Oxidation-Reduction Potential (ORP), Calcium (Ca^{2+}), Copper (Cu^{2+}), Cadmium (Cd^{3+}), Mercury (Hg^{+}), Lead (Pb^{2+}), Potassium (K^{+}), Nitrate ($NO_3{}^{-}$), Zinc (Zn^{2+}), and GPS. The Multi water quality checker: Horiba sensor U-53G models, Laquatwin ion water, and AND1100 Fluorimeter were used.

5.2.2 Experimental study areas

Bangkok, Thailand

The lower Chao Phraya river is located in the Nonthaburi and Bangkok Metropolitan area. The study area was from Nonthaburi province to the Bangkok Metropolitan area where there are 13.841949, 100.491073 to 13.692258, 100.491907, 26 kilometers. This research has designed two sampling sites: (1) sampling site (A, B, C, and D points). (2) global river flux site (E point). The sampling sites have been affected from the utilization of water, waste water, and water transportation. The global river flux site is the final point of checking area. This study has observed and evaluated the water quality from the drainpipe to the lower area and the accumulation of pollutant situation.

The 5 sampling points are: (1) A is Thanom non (13.841949, 100.491073). (2) B is Tea wate (13.772133, 100.500098). (3) C is Pra a tide (13.763545, 100.494025). (4) D is Si praya (13.728406, 100.513178). (5) E is Krungtap bridge (13.692558, 100.491907). The geographic location and sampling points of the study area are shown in Figure 5.1 and Table 5.4

Table 5.4 Description of the sampling points for river in Bangkok, Thailand.

Sampling points	Latitude	Longitude
A-thanom non	13.841949	100.491073
B-tea wate	13.772133	100.500098
C-pra a tide	13.763545	100.494025
D-si praya	13.728406	100.513178
E-krungtap bridge	13.692558	100.491907

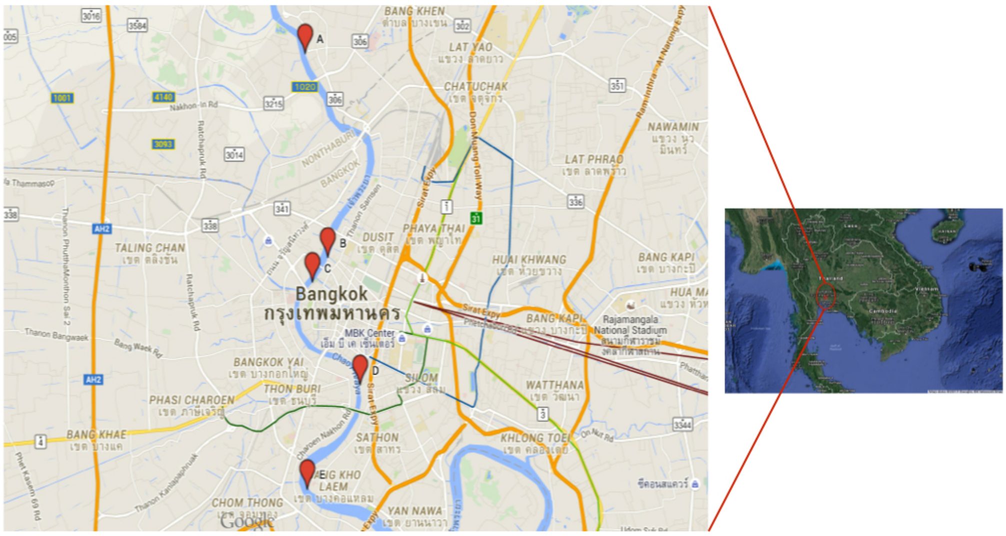


Fig. 5.1 The geographic location and sampling data point in Bangkok, Thailand. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Surabaya, Indonesia

Surabaya is the second largest city in Indonesia. Surabaya is located in East Java Province. The water from the Surabaya river is the main source for the urban population for activities such as drinking, gardening, and washing. From the Asian Urban Information center of Kobe (AUICK) action plan progress report, the Surabaya river has poor water quality. The important environmental problem of Surabaya city is from industrial waste discharge and domestic waste discharge. Today, both sides of Surabaya river have a lot of industrial companies including a paper factory, sugar factory, monosodium-glutamate factory, and chemical factory. As a consequence, wastewater from the manufacturing processes drains into the river.

The study areas for the water quality are in the rivers of Surabaya city, Indonesia at the Ngagel river, Jagir river, and Surabaya river. The description of the sampling points in Surabaya city, Indonesia is shown in Figure 5.2 and Table 5.5

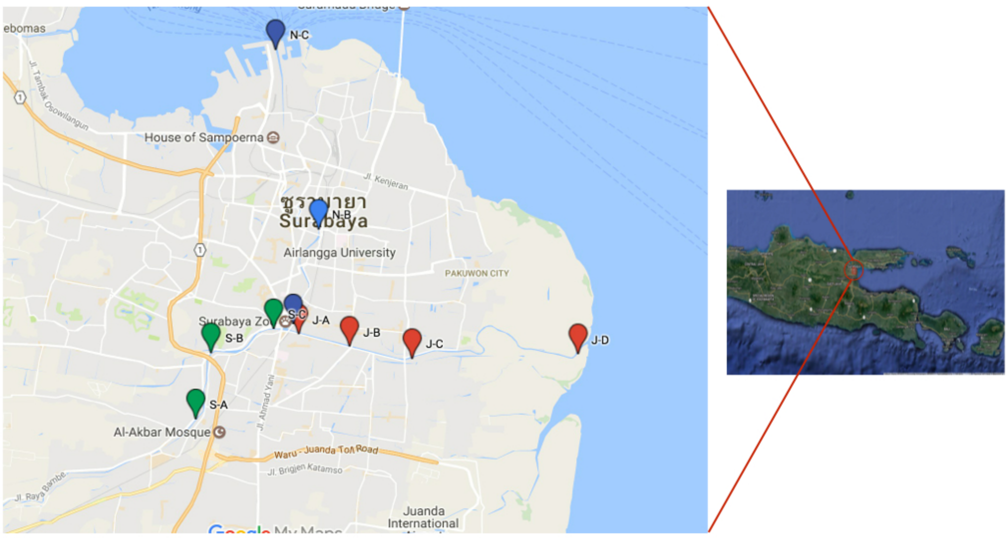


Fig. 5.2 The geographic location and sampling data point in Surabaya, Indonesia. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Table 5.5 Description of the sampling points for Rives in Surabaya, Indonesia.

Location (river)	Sampling points	Latitude	Longitude
Ngagel river	N-A	-7.299487	112.734737
	N-B	-7.263856	112.750372
	N-C	-7.199499	112.735368
Jagir river	J-A	-7.301354	112.743381
	J-B	-7.305796	112.761288
	J-C	-7.310150	112.783255
	J-D	-7.305158	112.806955
Surabaya river	S-A	-7.301354	112.743381
	S-B	-7.305796	112.761288
	S-C	-7.297746	112.741606

Hawaii (USA)

Hawaii is located in the Pacific Ocean of southwest of US, southeast of Japan, and southeast of Australia. Freshwater in Hawaii Island is used in the state for industrial activities, irrigation activities, and agricultural activities. Lots of wastewater from industrial processes run into not only the river but also the underground water.

The Nuuanu river, Manoa river, and Manoa canal are located in the central Island area and also the selected area for studying. The description of the sampling points in Hawaii, USA is shown in Figure 5.3 and Table 5.6.

Table 5.6 Description of the sampling points for river in Hawaii (USA).

Location (river)	Sampling points	Latitude	Longitude
Nuuanu	A	21.314362	157.861818
	B	21.314362	157.861818
Manoa	C	21.311147	157.808813
Ala Wai	D	21.274992	157.817526
	E	21.277997	157.821242
	F	21.277616	157.819960
	G	21.280087	157.823755
	H	21.283046	157.827202
	I	21.283438	157.827640
	J	21.287292	157.832102
	K	21.288718	157.834047
	L	21.287627	157.839780
	M	21.287560	157.843219
	N	21.284561	157.839613

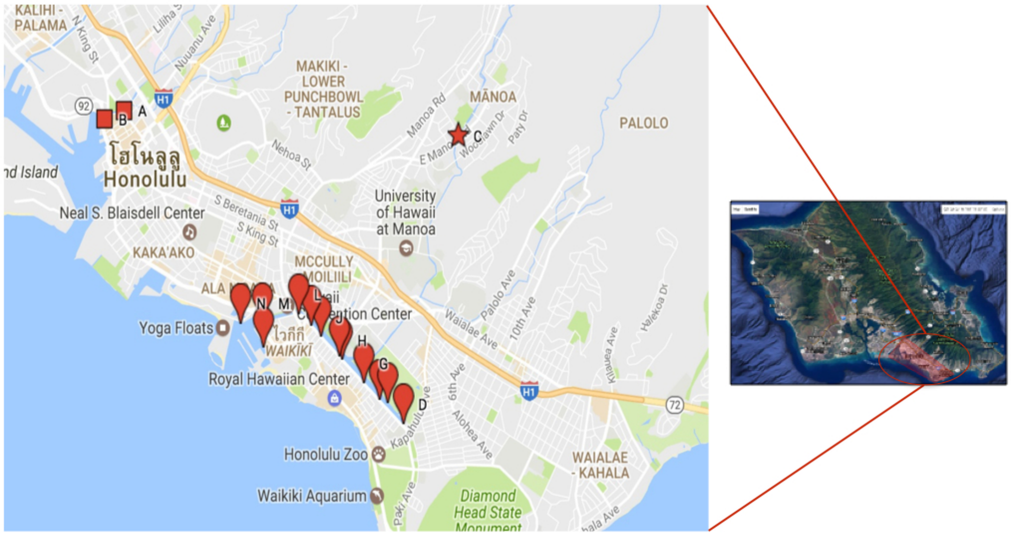


Fig. 5.3 The geographic location and sampling data point in Hawaii, USA. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Pori, Finland

For SYKE report, Finland is a country of thousands of lakes, rivers, islands, and is rich in surface water. Finland's shallow lakes are easily contaminated by pollution. Even relatively low concentrations of excess nutrients, acidic deposition, or other harmful contaminants can easily disrupt their sensitive aquatic ecosystems. Over half of the nutrient load causing eutrophication in water bodies come from agricultural activities, industrial activities, settlement, and communities. Communities are still sources of nitrogen discharge, while sparsely populated areas result in a significant portion of Finland's phosphorous discharges. To clarify, communities mainly pollute and change the condition of the water in lakes and rivers in Finland.

Pori is a municipality and city, which is located on the west coast of Finland and 10 kilometers from the Gulf of Bothnia. Kokemäenjoki river is the fourth largest catchment in Finland, it ends up in the Baltic sea, where it originates at lake Liekovesi in the Pirkanmaa region. The water from Kokemäenjoki river is the main source of agriculture, aquatic life, industry, water supply, and recreation. Kokemäenjoki river flows to the Gulf of Bothnia at Pori in the Satakunta region. The pollutant loading in Kokemäenjoki river originates from agricultural activities, forestry, and settlements [51]. The description of the sampling points in Pori, Finland is shown in Figure 5.4 and Table 5.7.

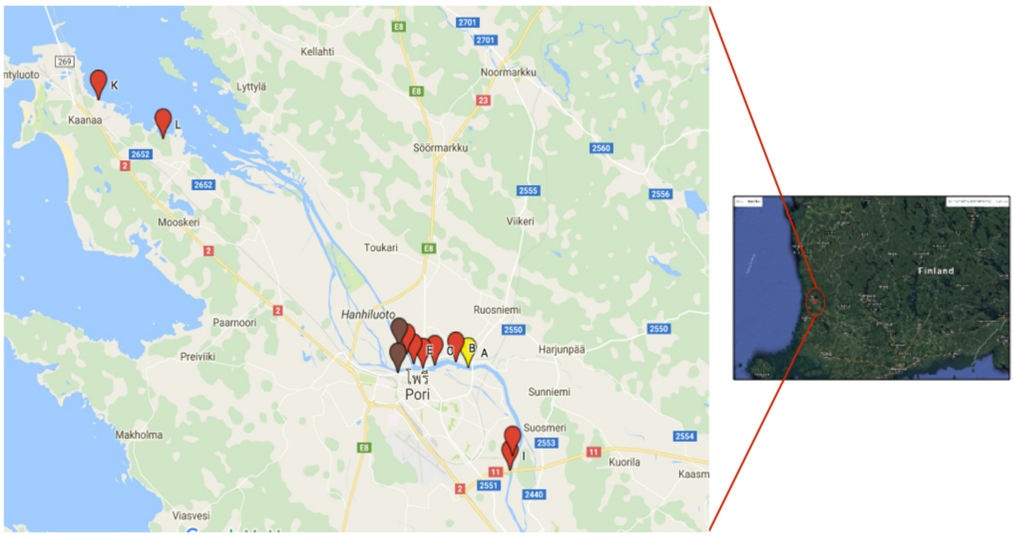


Fig. 5.4 The geographic location and sampling data point in Pori, Finland. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Table 5.7 Description of the sampling points for river in Pori, Finland.

Location (river)	Sampling points	Latitude	Longitude
Kokemäenjoki	A	61.491747	21.837152
	B	61.493654	21.827547
	C	61.492496	21.810902
	D	61.491615	21.801848
	E	61.492974	21.794521
	F	61.496545	21.788986
	G	61.498453	21.783121
	H	61.490005	21.781944
	I	61.456459	21.869526
	J	61.461662	21.871684

Riga, Latvia

Riga, Latvia. Riga is the largest city in the Baltic States and lies on the Gulf of Riga. Some of the freshwater areas in Riga began experiencing environmental deterioration in the era of Soviet collective farming and a wave of hydroelectric power project. Water runoff from those activities caused pollution in the water resources. The description of the sampling points in Riga, Latvia is shown in Figure 5.5 and Table 5.8.

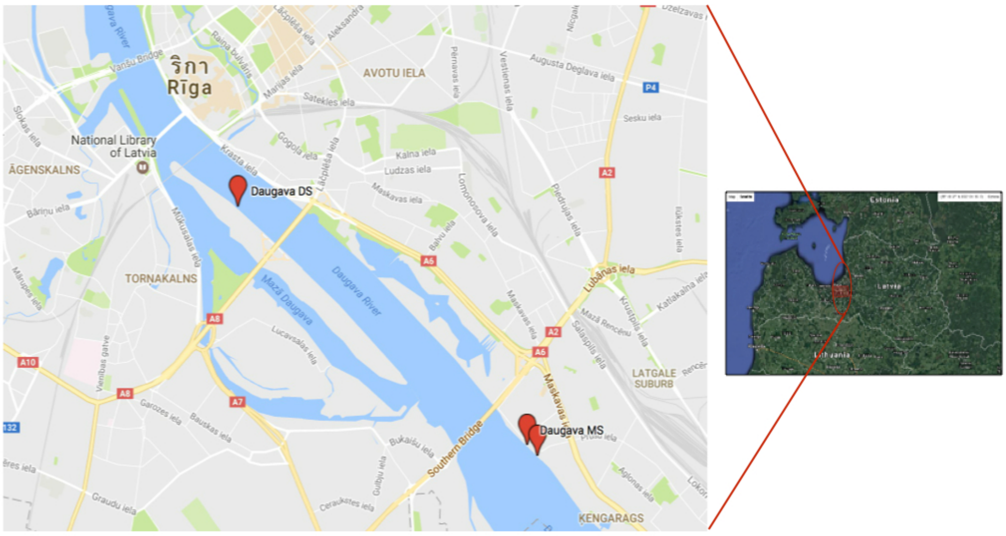


Fig. 5.5 The geographic location and sampling data point in Riga, Latvia. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Table 5.8 Description of the sampling points for river in Riga, Latvia.

Location (river)	Sampling points	Latitude	Longitude
Daugava	A	56.913480	24.169145
	B	56.914538	24.167233
	C	56.937357	24.114167

Vientiane,Laos

Laos is located in an area rich in mineral resources. The main industry in Laos is mining, which has caused pollution in the river and atmosphere. There are several processes of mining and other industrial activities are nearby in an important river in the Vientiane areas such as the Mekong river, Nam Lik river, and Nam Ngum

River in the study areas. The description of the sampling points in Vientiane, Laos is shown in Figure 5.6 and Table 5.9

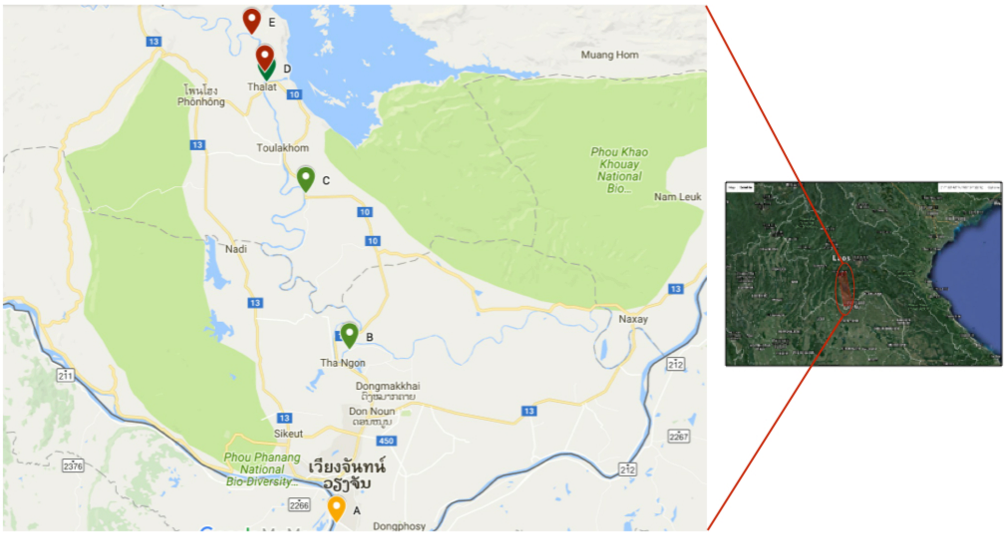


Fig. 5.6 The geographic location and sampling data point in Vientiane, Laos. (Left is courtesy of Google and Right is of United States Geological Survey, USGS).

Table 5.9 Description of the sampling points for river in Vientiane, Laos.

Location (river)	Sampling points	Latitude	Longitude
Mekong	A	17.907442	102.616652
Nam Ngum	B	18.510329	102.635581
	C	18.368835	102.571367
	D	18.524930	102.513324
	E	18.539164	102.510560
Nam Lik	F	18.590006	102.491119

Chapter 6

Analysis Results

This chapter describes the analysis results of the implementation. Firstly, the visualization of the water-quality changing analysis with the 5D World Map System is used for comparing water quality condition over multiple places and time series change by integrating the Water Quality Index (WQI) and the Metal Index (MI) calculations. Secondly, the river SPA Processes (rSPA) from the SPA Processes concept, which is used for detection of the critical contaminants points, identifies the effect class of multiple-water-quality-parameters and real-time warning detection of critical contaminants and classification of multiple-parameter-waters. Thirdly, the multi-dimensional water-quality and semantic space creation are described in a new approach interpreting environments by the value information and language information of intellectual activities in various environmental meanings to society. Fourthly, the river Heavy Metal Evaluation Index (rHMEI) and semantic space creation are described for analyzing water quality in several categories, evaluating water quality in terms of heavy metal, and numerical interpretation of values of heavy metals to feature semantic wording. Fifthly, the progress of processing in the SPA process in semantic-ordering functions, which proposed a semantic space creation (a proposed dynamic-dimension for river-water-quality interpretation) and semantic space parameter-relatedness weighting method of diverse river-water-quality variability takes place. All of these are used to analyze the meta-level knowledge of the database system for water-quality data, to identify the different water-quality in different places from a global point of view level, and presenting a global-scale ranking of water quality.

6.1 The result of Analysis and Visualization with 5D World Map System

6.1.1 Water-quality visualized by using 5D World Map System

Thailand

The Physical, Chemical, and Biological parameters of water resource between 2004 and 2014 are analyzed and visualized in 5DWM. The comparison of the values at each station is achieved by using different levels of color. The water parameters are turbidity, pH, conductivity, DO, BOD, TS, TDS, SS, total coliform bacteria, fecal coliform bacteria, and heavy metal etc. from 25 rivers (Ping river, Kui Bure river, Nan river, Petchabun river, Yom river, Wang river, Kuang river, Kok river, Kwan Phrayao river, Mea jang river, Lamtakhon river, Chee river, Mun river, Ing river, Loei river, Rayong river, Welu river, Chao Phraya river, Kheaw yai river, Kheaw noi river, Thajen river, Pattane river, Chumporn river, Pha sak river, and Trang river).

From the visualized result, the concentration of water pollutions downstream is more than that upstream in each river because the pollutant is accumulated in rivers. Because the water utilization from rivers is used for purposes such as agricultural, industry, and by communities, this study result found the relationship of the water pollution source with the population rate, the types of agriculture activities, and industrial activities. Moreover, the result is shown in Figures 6.1, 6.2 and 6.3. The visualization results from the data analysis function in 5DWM are shown in 2 characteristics of the pollutants, which are accumulated in downstream of both industrial and/or municipal areas. The result is outlined as follows:

- The highest pollution of the river was downstream of the investigation; the study found the pollutants accumulated from upstream to downstream in the Ping river, Kui Bure river, Nan river, and Petchabun river.
- The highest pollution occurred at the middle of the river under investigation, the study found pollutants accumulated both in industrial areas and/or municipal areas in the Yom river, Wang river, Kuang river, Kok river, Kwan Phrayao river, Mea jang river, Lamtakhon river, Chee river, Mun river, Ing river, Loei river, Rayong river, Welu river, Chao phraya river, Kheaw yai

river, Kheaw noi river, Thajen river, Pattane river, Chumporn river, Pha sak river, and Trang river.

Surabaya, Indonesia

The analysis of water-quality by using the visualization function on 5DWM is shown in Figure 6.4 and analyzed in time lapse as below.

- The pH parameter analysis by using the visualization function on 5DWM in time lapse: The pH value is a slightly changing value levels between 7.09 and 8.89 (the optimal range for river water or fresh water).

- The Salinity and Total Dissolved Solid (TDS) parameters analysis by using the visualization function on 5DWM in time lapse: The results from visualization by 5DWM found the pollutants accumulated downstream in all 3 rivers for which the highest value of salinity was found in the Ngagel river (C point). The concentration of salinity at this point is high because of the ion elements and salt from seawater flows into the river water at this point, meanwhile, the sea water density is higher than that of river water and fresh water because the dissolved salts increase the mass by a larger proportion in sodium ion (Na^{+}) and chloride ion (Cl^{-}) mainly in solution. Conversely, river water has different calcium ion (Ca^{2+}) and bicarbonate ($HCO_3{}^{-}$) solutions.

- The Dissolved Oxygen (DO) parameter analysis proceeds by using the visualization function in 5DWM in time lapse: The concentration of dissolved solids is non-stable because of activity in the water body and the time of sampling of the data. The impact of continuous human activities is the frequency of river transportation while data were collected in this experimental study.

- The Turbidity parameter analysis, by using the visualization function in 5DWM in time lapse, was able to determine critical concentration point as the Ngagel river (C points) because it is closer to the harbor with highly turbulent water.

- The productivity parameter analysis uses the visualization function in 5DWM in time lapse: The results from the visualization by 5DWM show that pollutants are accumulated downstream in all 3 rivers. The highest value of conductivity is in the Ngagel river (C points) because the ion elements from seawater flows into the river water are substantial.

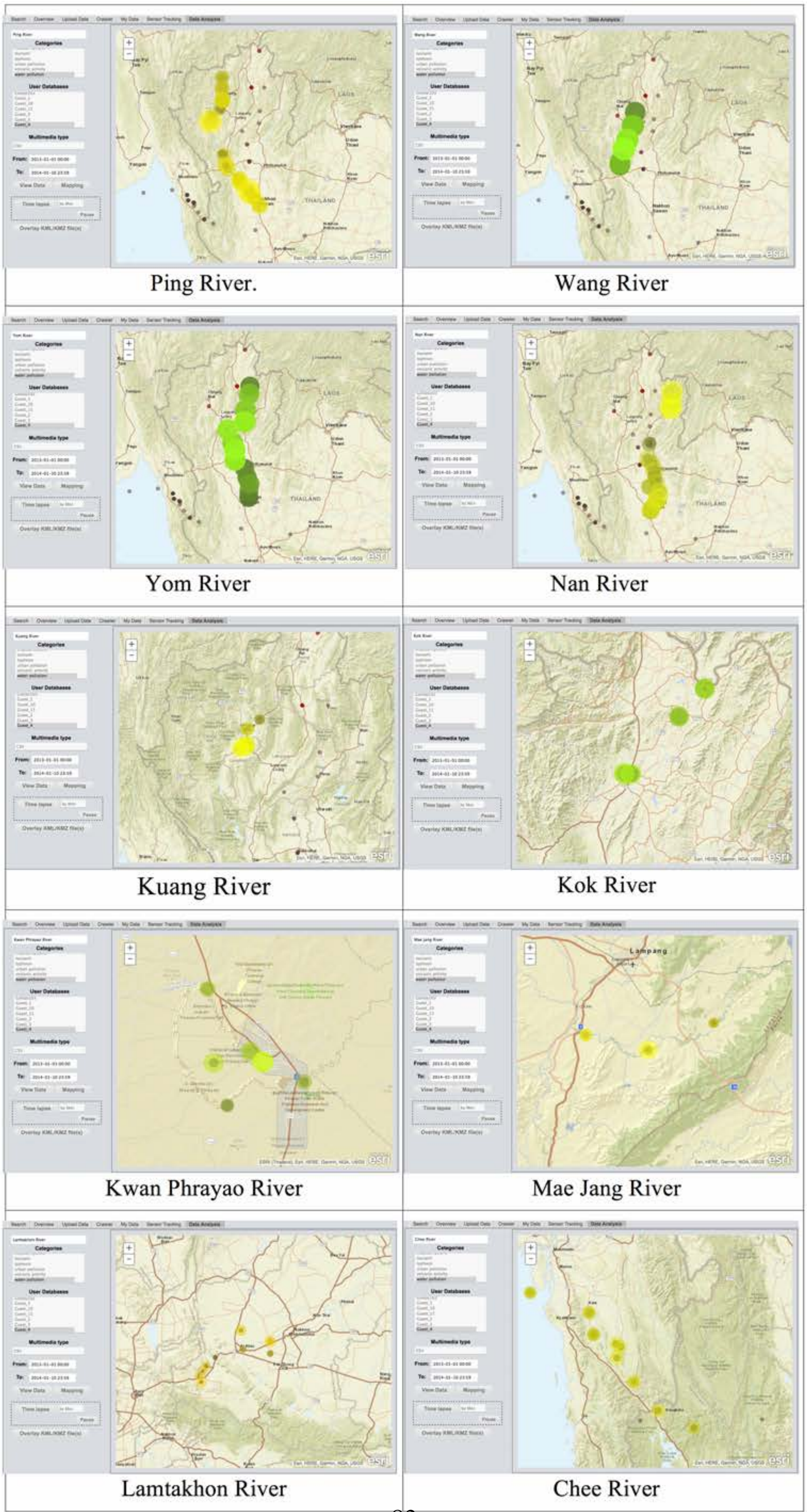


Fig. 6.1 The results of water-quality analysis by using visualization function on 5D World Map System in Thailand.

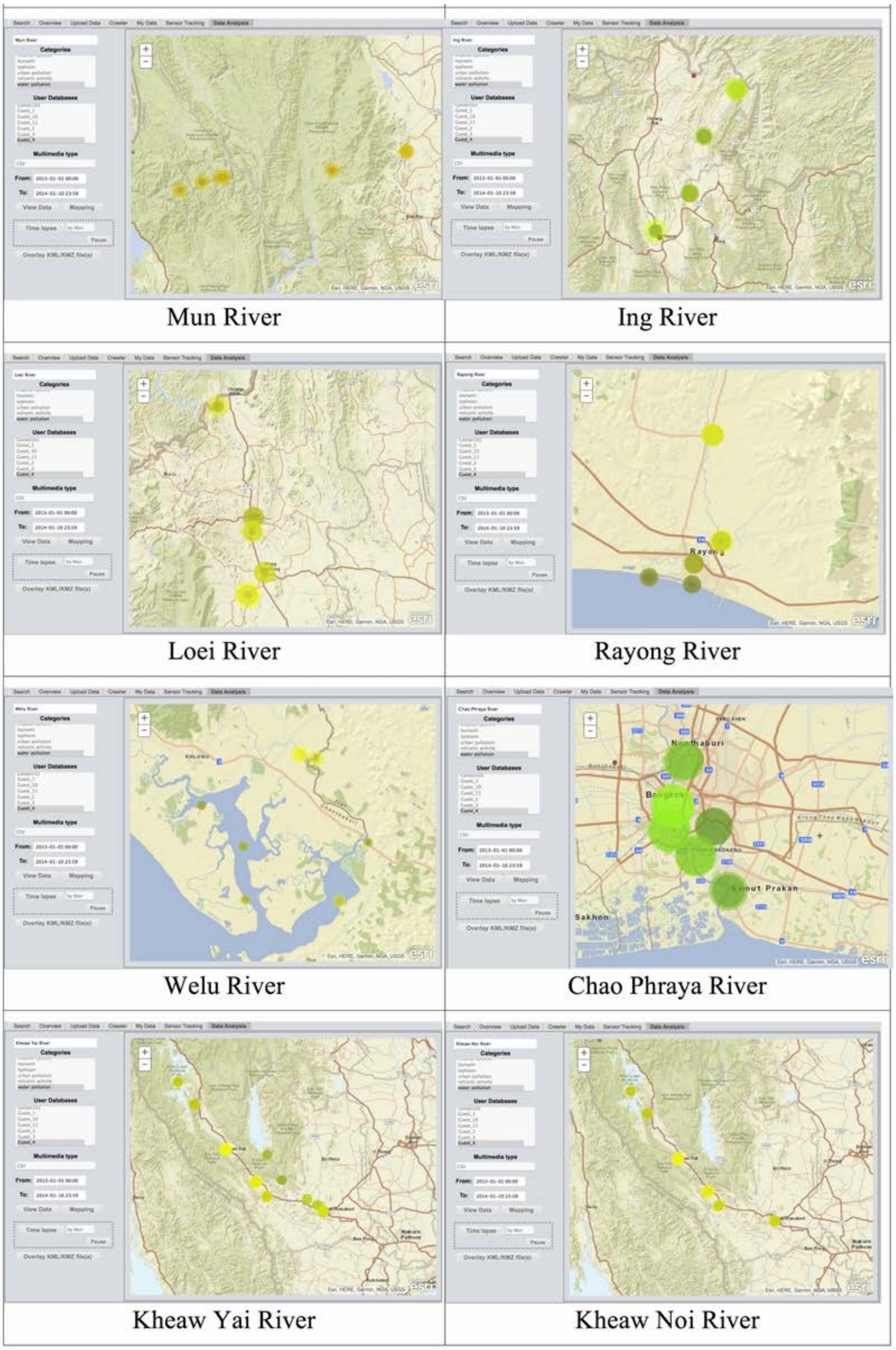


Fig. 6.2 The results of water-quality analysis by using visualization function on 5D World Map System in Thailand (*Cont*.).

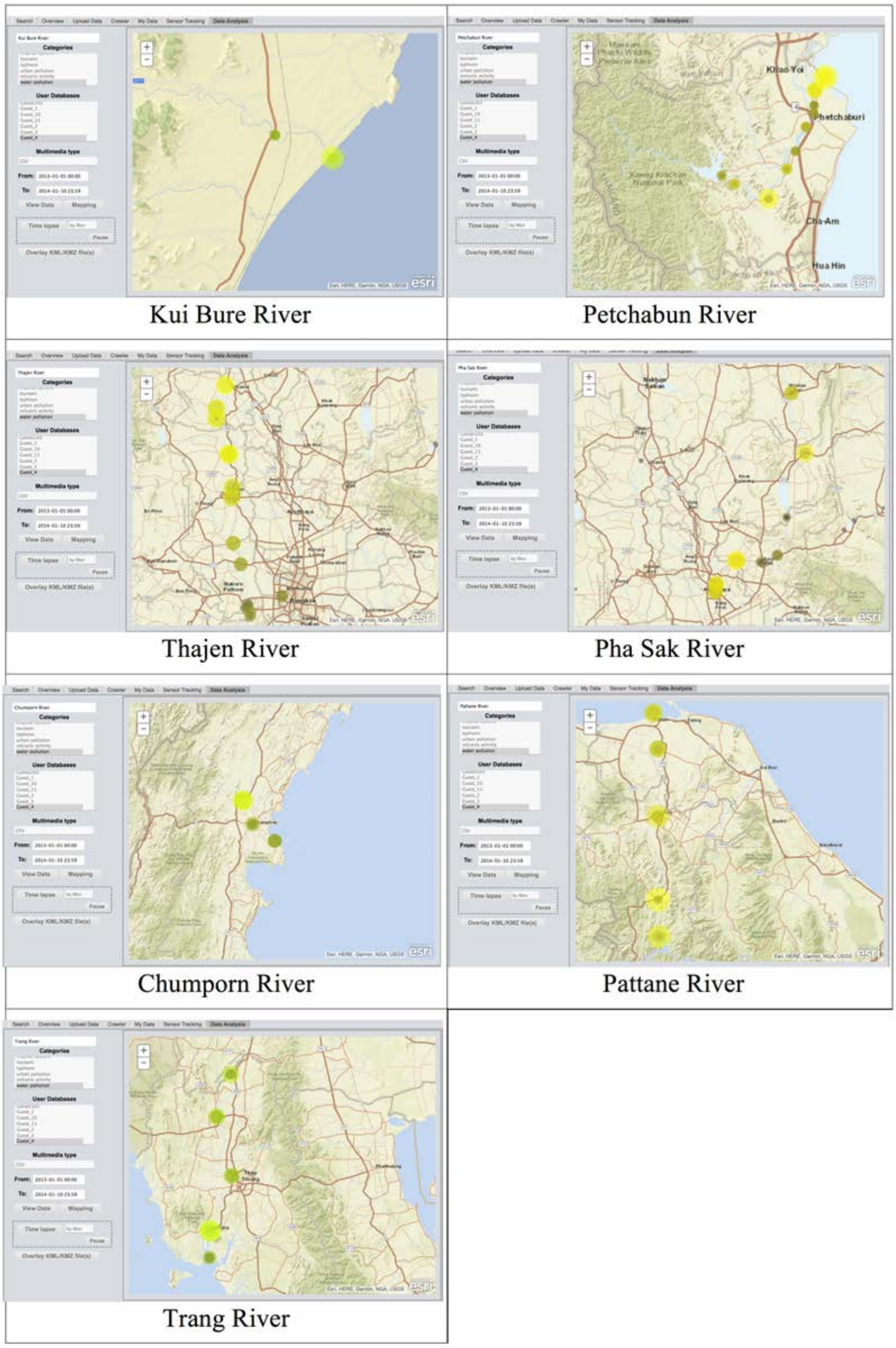
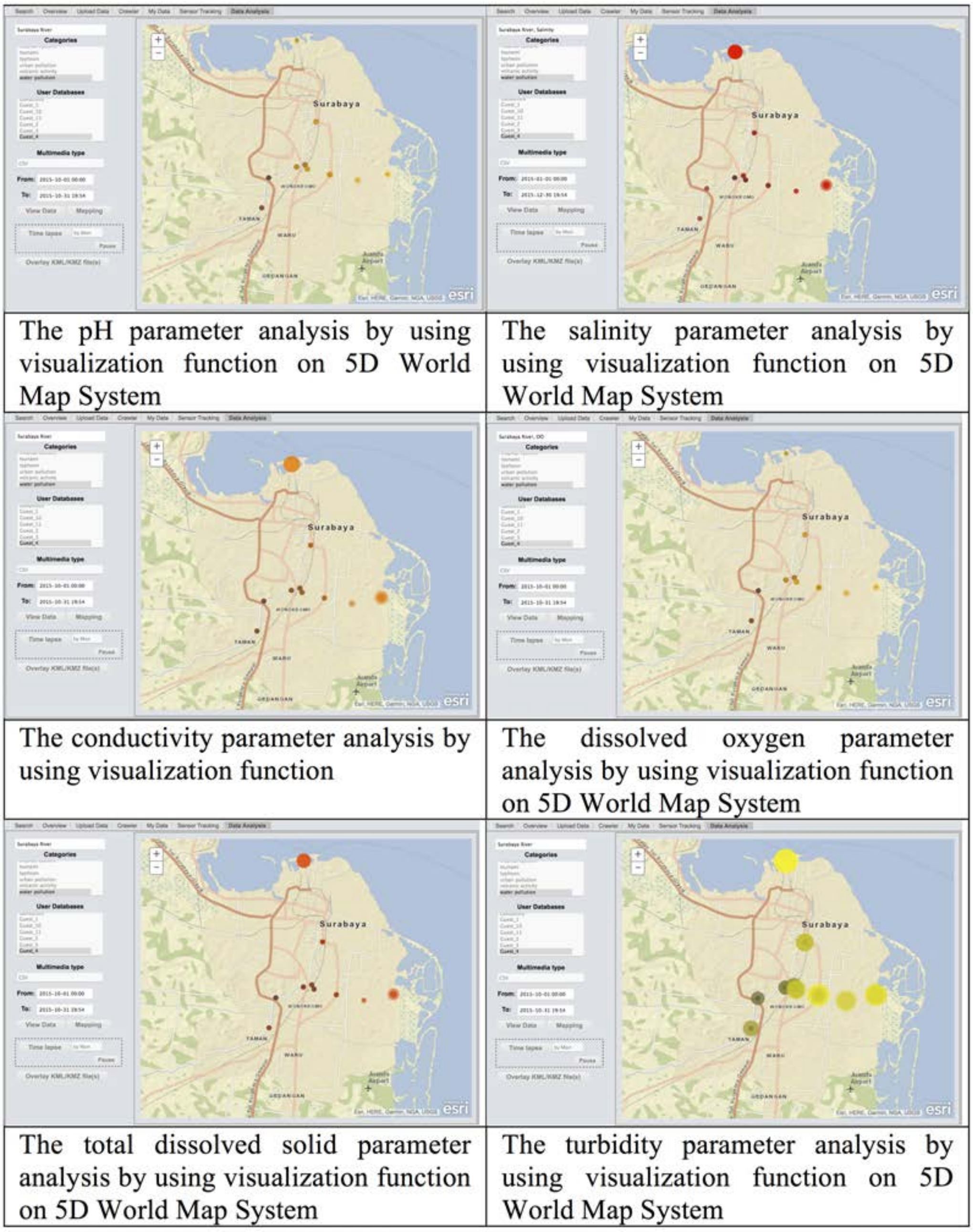


Fig. 6.3 The results of water-quality analysis by using visualization function on 5D World Map System Thailand (*Cont*.).



The pH parameter analysis by using visualization function on 5D World Map System

The salinity parameter analysis by using visualization function on 5D World Map System

The conductivity parameter analysis by using visualization function

The dissolved oxygen parameter analysis by using visualization function on 5D World Map System

The total dissolved solid parameter analysis by using visualization function on 5D World Map System

The turbidity parameter analysis by using visualization function on 5D World Map System

Fig. 6.4 The results of water-quality analysis by using visualization function on 5D World Map System in Surabaya, Indonesia.

Water-quality visualized by using Water Quality Index

This subsection analyzed water-quality data for 2004, 2006, 2008, 2010, 2012, and 2014 in the Ping, Nan, and Chao Phraya rivers, which are important rivers in Thailand, using the WQI indicator. In this subsection the analyzed water-quality is for Aquatic life and Irrigation. WQI for Irrigation and Aquatic life was computed by using guidelines from the water quality standards of the water body in Thailand (1999) [47], FAO (1994) [36], and CCME (1999) [37].

Table 4. shows that the WQI of the Ping, Nan, and Chao Phraya Rivers range between 0.274 and 32.697 and 0.038 and 38.534 for Irrigation and Aquatic life respectively. Ping, Nan, and Chao Phraya rivers can be classified at the excellence to good level. The warning of the water quality index (WQI) for Irrigation and Aquatic life is shown in Figure 6.5

Water-quality visualized by using Metal Index

This subsection analyzed the water-quality data for 2004, 2006, 2008, 2010, 2012, and 2014 in the Ping, Nan, and Chao Phraya rivers, which are important rivers of Thailand, by using the MI indicator. In this subsection the analyzed water-quality is for Aquatic life and Irrigation. MI for Irrigation and Aquatic life was computed using the guidelines of the standards in water quality of water body in Thailand [47], FAO (1994) [36], and CCME (1999) [37].

In the Metal Index (MI) for Irrigation and Aquatic life, the MI reached 92.902 and 1803.032 in the Ping river in 2014 because of the high concentrations of Cadmium, Manganese, and Zinc. From the results, a value of MI > 1 shows the threshold for warning using PostgreSQL. The threshold of warning for the Metal Index (MI) for Irrigation and Aquatic life is shown in Figure 6.6 and 6.7

ID	WQI		Year	River	Location	Latitude	Longitude
	Irrigation	Aquatic live					
1	0.623	0.038	2004	Nan	Phitsanulok	17.0481337108011	100.181566086985
2	0.664	0.849	2006	Nan	Phitsanulok	17.0481337108012	100.181566086987
3	0.315	4.559	2008	Nan	Phitsanulok	17.0481337108013	100.181566086988
4	0.372	4.928	2010	Nan	Phitsanulok	17.0481337108014	100.181566086989
5	0.948	6.768	2012	Nan	Phitsanulok	17.0481337108015	100.181566086990
6	0.358	4.764	2014	Nan	Phitsanulok	17.0481337108016	100.181566086991
7	1.997	0.044	2004	Nan	Phichit	16.3597027941911	100.111974161327
8	2.141	1.118	2006	Nan	Phichit	16.3597027941912	100.111974161329
9	2.998	6.466	2008	Nan	Phichit	16.3597027941913	100.111974161330
10	0.674	3.833	2010	Nan	Phichit	16.3597027941914	100.111974161331
11	0.736	2.932	2012	Nan	Phichit	16.3597027941915	100.111974161332
12	1.533	2.968	2014	Nan	Phichit	16.3597027941916	100.111974161333
13	1.996	10.214	2004	Ping	Chiang Mai	19.1497126669801	98.9887785132537
14	1.792	0.343	2006	Ping	Chiang Mai	19.1497126669802	98.9887785132538
15	14.927	0.914	2008	Ping	Chiang Mai	19.1497126669803	98.9887785132539
16	1.239	0.737	2010	Ping	Chiang Mai	19.1497126669804	98.9887785132540
17	9.624	0.947	2012	Ping	Chiang Mai	19.1497126669805	98.9887785132541
18	0.678	0.539	2014	Ping	Chiang Mai	19.1497126669806	98.9887785132542
19	8.986	17.738	2004	Ping	Nakhon Sawan	15.7200393987260	100.144566170258
20	9.649	3.122	2006	Ping	Nakhon Sawan	15.7200393987270	100.144566170260
21	0.577	2.534	2008	Ping	Nakhon Sawan	15.7200393987280	100.144566170261
22	0.457	8.334	2010	Ping	Nakhon Sawan	15.7200393987290	100.144566170262
23	0.715	4.101	2012	Ping	Nakhon Sawan	15.7200393987300	100.144566170263
24	0.603	38.534	2014	Ping	Nakhon Sawan	15.7200393987310	100.144566170264
25	0.726	9.506	2004	Chao Phraya	Chai nat	15.1559182073315	100.183972007058
26	0.389	0.552	2006	Chao Phraya	Chai nat	15.1559182073316	100.183972007060
27	1.525	0.466	2008	Chao Phraya	Chai nat	15.1559182073317	100.183972007061
28	0.418	0.288	2010	Chao Phraya	Chai nat	15.1559182073318	100.183972007062
29	3.114	0.317	2012	Chao Phraya	Chai nat	15.1559182073319	100.183972007063
30	0.274	3.991	2014	Chao Phraya	Chai nat	15.1559182073320	100.183972007064
31	32.697	7.748	2004	Chao Phraya	Bangkok	13.7028182431342	100.569989656312
32	21.414	0.478	2006	Chao Phraya	Bangkok	13.7028182431344	100.569989656314
33	24.020	0.554	2008	Chao Phraya	Bangkok	13.7028182431345	100.569989656315
34	1.418	0.659	2010	Chao Phraya	Bangkok	13.7028182431346	100.569989656316
35	8.723	0.567	2012	Chao Phraya	Bangkok	13.7028182431347	100.569989656317
36	11.965	5.369	2014	Chao Phraya	Bangkok	13.7028182431348	100.569989656318

Fig. 6.5 The results of Water Quality Index (WQI) for Irrigation and Aquatic life.

id	value	year	river	location
2	2.133	2006	Nan	Phisanulok
3	3.140	2008	Nan	Phisanulok
4	3.357	2010	Nan	Phisanulok
5	8.129	2012	Nan	Phisanulok
6	12.501	2014	Nan	Phisanulok
8	1.952	2006	Nan	Phichit
9	5.408	2008	Nan	Phichit
10	2.062	2010	Nan	Phichit
11	3.807	2012	Nan	Phichit
12	10.501	2014	Nan	Phichit
13	76.401	2004	Ping	Chiangmai
14	1.585	2006	Ping	Chiangmai
16	8.565	2010	Ping	Chiangmai
17	3.651	2012	Ping	Chiangmai
18	9.510	2014	Ping	Chiangmai
19	30.610	2004	Ping	Nakhonsawan
20	1.782	2006	Ping	Nakhonsawan
21	1,481	2008	Ping	Nakhonsawan
22	7.632	2010	Ping	Nakhonsawan
23	1.680	2012	Ping	Nakhonsawan
24	92.902	2014	Ping	Nakhonsawan
25	47.901	2004	Chaophraya	Chainat
26	1.257	2006	Chaophraya	Chainat
29	1.085	2012	Chaophraya	Chainat
30	29.036	2014	Chaophraya	Chainat
31	33.951	2004	Chaophraya	Bangkok
33	2.741	2008	Chaophraya	Bangkok
34	1.383	2010	Chaophraya	Bangkok
36	33.106	2014	Chaophraya	Bangkok

(29 rows)

Fig. 6.6 The results of threshold warning of Metal Index (MI) for Aquatic life.

id	value	year	river	location
2	20.872	2006	Nan	Phisanulok
3	14.297	2008	Nan	Phisanulok
4	7.520	2010	Nan	Phisanulok
5	12.324	2012	Nan	Phisanulok
6	35.035	2014	Nan	Phisanulok
8	28.239	2006	Nan	Phichit
9	18.319	2008	Nan	Phichit
10	6.171	2010	Nan	Phichit
11	10.044	2012	Nan	Phichit
12	33.035	2014	Nan	Phichit
13	698.939	2004	Ping	Chiangnai
14	6.364	2006	Ping	Chiangnai
15	10.764	2008	Ping	Chiangnai
16	13.807	2010	Ping	Chiangnai
17	17.605	2012	Ping	Chiangnai
18	38.193	2014	Ping	Chiangnai
19	970.568	2004	Ping	Nakhonsawan
20	7.128	2006	Ping	Nakhonsawan
21	15.943	2008	Ping	Nakhonsawan
22	11.609	2010	Ping	Nakhonsawan
23	14.960	2012	Ping	Nakhonsawan
24	1803.032	2014	Ping	Nakhonsawan
25	157.796	2004	Chaophraya	Chainat
26	12.718	2006	Chaophraya	Chainat
27	12.489	2008	Chaophraya	Chainat
28	9.446	2010	Chaophraya	Chainat
29	10.561	2012	Chaophraya	Chainat
30	148.068	2014	Chaophraya	Chainat
32	10.461	2006	Chaophraya	Bangkok
31	249.582	2004	Chaophraya	Bangkok
33	109.284	2008	Chaophraya	Bangkok
34	14.289	2010	Chaophraya	Bangkok
35	11.323	2012	Chaophraya	Bangkok
36	190.093	2014	Chaophraya	Bangkok

(34 rows)

Fig. 6.7 The results of threshold warning of Metal Index (MI) for Irrigation.

6.2 Water-quality Analysis by rSPA Processes

Water-quality analysis is one of the most important aspects of designing environmental systems. It is necessary to realize detection and classification processes in systems for water quality analysis. This section presents the feasibility and effectiveness of the rSPA processes to realize a warming system for the results for pollutants for the public for preparing the protection and treatment processes in industry. The rSPA process detects the critical contaminant points and identifies the effect class of multiple-water-quality parameters. The result come from sampling the water quality by analyzing the raw data at several points. In the analyzed results by points, there are 2 groups of parameters:

- The first group is of constantly changing parameters (temperature, pH, turbidity DO, and ORP). These parameters change between points and the values depend on environmental factors which are organic particles, decomposition of the plant, animal matter, inorganic particles, heavy rain, algae blooms, and transportation. All of the environmental factors make the turbulence in the water body, measured through the turbidity parameter, increase after transportation and wastewater drainage.
- The second group is of accumulative parameters (conductivity, salinity, and tds). These accumulated from the upstream to the downstream of the river and the highest value is at E point.

6.2.1 The critical contaminate detection of multiple-parameter waters

Using result from the rSPA process and with program of PostgresSQL, the system detected the input value and used the standard threshold value (from the knowledge database which was designed in the materials and method step) to find the critical contaminated points as

- Conductivity is 8 points.
- Dissolved Oxygen (DO) is 12 points.
- Salinity is 15 points.
- Total Dissolved Solid (TDS) is 2 points.
- Turbidity is 10 points.

The results in detail are shown in Figure 6.8 - Figure 6.12

id	ndate	location	latitude	longitude	conductivity
2	2015-03-15	B-tea wate	13.772133	100.500098	3420
3	2015-03-15	C-pra a tide	13.763545	100.494025	3874
4	2015-03-15	D-si praya	13.728406	100.513178	5901
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	8681
9	2015-03-20	D-si praya	13.728406	100.513178	2358
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	4351
14	2015-03-25	D-si praya	13.728406	100.513178	2273
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	4122

(8 rows)

Fig. 6.8 The results of critical contaminate detection of Conductivity: The result showed the critical value (left column) and information of points.

id	ndate	location	latitude	longitude	dissolvedoxygen
2	2015-03-15	B-tea wate	13.772133	100.500098	2.01
3	2015-03-15	C-pra a tide	13.763545	100.494025	3.01
6	2015-03-20	A-thanomnon	13.841949	100.491073	2.559
7	2015-03-20	B-tea wate	13.772133	100.500098	2.533
8	2015-03-20	C-pra a tide	13.763545	100.494025	2.531
9	2015-03-20	D-si praya	13.728406	100.513178	2.463
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	3.309
11	2015-03-25	A-thanomnon	13.841949	100.491073	2.888
12	2015-03-25	B-tea wate	13.772133	100.500098	2.611
13	2015-03-25	C-pra a tide	13.763545	100.494025	2.611
14	2015-03-25	D-si praya	13.728406	100.513178	2.651
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	1.695

(12 rows)

Fig. 6.9 The results of critical contaminate detection of Dissolved Oxygen (DO): The result showed the critical value (left column) and information of points.

id	ndate	location	latitude	longitude	salinity

(0 rows)

Fig. 6.10 The results of critical contaminate detection of Salinity: The result showed no the critical value and information of points because no value of each point more that standard threshold.

id	ndate	location	latitude	longitude	tds
4	2015-03-15	D-si praya	13.728406	100.513178	3753.185
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	5572.634

(2 rows)

Fig. 6.11 The results of critical contaminate detection of Total Dissolved Solid (TDS): The result showed the critical value (left column) and information of points.

id	ndate	location	latitude	longitude	turbidity
4	2015-03-15	D-si praya	13.728406	100.513178	512.9
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	313.96
6	2015-03-20	A-thanomnon	13.841949	100.491073	86.82
7	2015-03-20	B-tea wate	13.772133	100.500098	64.38
8	2015-03-20	C-pra a tide	13.763545	100.494025	104.95
9	2015-03-20	D-si praya	13.728406	100.513178	71.48
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	52.59
11	2015-03-25	A-thanomnon	13.841949	100.491073	54.676
12	2015-03-25	B-tea wate	13.772133	100.500098	135.74
14	2015-03-25	D-si praya	13.728406	100.513178	74.94

(10 rows)

Fig. 6.12 The results of critical contaminate detection of Turbidity: The result showed the critical value (left column) and information of points.

6.2.2 The effect classification

Using the result from the rSPA process and applying PostgresSQL, the system detected the input value and used the range effect for classification (from the knowledge database which was designed in the materials and method step). The results of the rSPA found the effect class of the parameters as:

- The effect classification of Conductivity found 3 classes: The result is shown for 15 data sets; an intermediate effect 7 points, high effect 2 points, and very high effect 6 points. The results in detail are shown in Figure 6.13.
- The effect classification of Dissolved Oxygen (DO) found 2 classes: The result is shown to 15 data set as a high effect 4 points and very high effect 11 points. The results in detail are shown in Figure 6.14.
- The effect classification of Total Dissolved Solid (TDS) found 4 classes: The result is shown for 15 data sets; a low effect 1 point, intermediate effect 2 points, high effect 2 points, and very high effect 10 points. The results in detail are shown in Figure 6.15.
- The effect classification of Turbidity found 5 classes: The result is shown for 15 data sets; a completely safe 1 point, low effect 1 point, intermediate effect 2 points, high effect 1 point, and very high effect 10 points. The results in detail are shown in Figure 6.16.

id	ndate	location	latitude	longitude	conductivity	effect
2	2015-03-15	B-tea wate	13.772133	100.500098	3420	Very high effect
3	2015-03-15	C-pra a tide	13.763545	100.494025	3874	Very high effect
4	2015-03-15	D-si praya	13.728406	100.513178	5901	Very high effect
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	8681	Very high effect
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	4351	Very high effect
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	4122	Very high effect
9	2015-03-20	D-si praya	13.728406	100.513178	2358	High effect
14	2015-03-25	D-si praya	13.728406	100.513178	2273	High effect
1	2015-03-15	A-thanomnon	13.841949	100.491073	1264	Intermediate effect
6	2015-03-20	A-thanomnon	13.841949	100.491073	800.2	Intermediate effect
7	2015-03-20	B-tea wate	13.772133	100.500098	1615	Intermediate effect
8	2015-03-20	C-pra a tide	13.763545	100.494025	1615	Intermediate effect
11	2015-03-25	A-thanomnon	13.841949	100.491073	899.6	Intermediate effect
12	2015-03-25	B-tea wate	13.772133	100.500098	1845	Intermediate effect
13	2015-03-25	C-pra a tide	13.763545	100.494025	1873	Intermediate effect

(15 rows)

Fig. 6.13 The results of classification of Conductivity: The result showed the value, effect class and information of points (2 last left column).

id	ndate	location	latitude	longitude	dissolvedoxygen	effect
2	2015-03-15	B-tea wate	13.772133	100.500098	2.01	Very high effect
6	2015-03-20	A-thanomnon	13.841949	100.491073	2.559	Very high effect
7	2015-03-20	B-tea wate	13.772133	100.500098	2.533	Very high effect
8	2015-03-20	C-pra a tide	13.763545	100.494025	2.531	Very high effect
9	2015-03-20	D-si praya	13.728406	100.513178	2.463	Very high effect
11	2015-03-25	A-thanomnon	13.841949	100.491073	2.888	Very high effect
12	2015-03-25	B-tea wate	13.772133	100.500098	2.611	Very high effect
13	2015-03-25	C-pra a tide	13.763545	100.494025	2.611	Very high effect
14	2015-03-25	D-si praya	13.728406	100.513178	2.651	Very high effect
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	1.695	Very high effect
1	2015-03-15	A-thanomnon	13.841949	100.491073	1.79	Very high effect
3	2015-03-15	C-pra a tide	13.763545	100.494025	3.01	High effect
4	2015-03-15	D-si praya	13.728406	100.513178	4.518	High effect
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	4.181	High effect
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	3.309	High effect

(15 rows)

Fig. 6.14 The results of classification of Dissolved Oxygen (DO): The result showed the value, effect class and information of points (2 last left column).

id	ndate	location	latitude	longitude	tds	effect
2	2015-03-15	B-tea wate	13.772133	100.500098	2190.273	Very high effect
3	2015-03-15	C-pra a tide	13.763545	100.494025	2479	Very high effect
4	2015-03-15	D-si praya	13.728406	100.513178	3753.185	Very high effect
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	5572.634	Very high effect
9	2015-03-20	D-si praya	13.728406	100.513178	1597.691	Very high effect
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	2977.24	Very high effect
12	2015-03-25	B-tea wate	13.772133	100.500098	1283.416	Very high effect
13	2015-03-25	C-pra a tide	13.763545	100.494025	1317.161	Very high effect
14	2015-03-25	D-si praya	13.728406	100.513178	1610.951	Very high effect
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	2953.151	Very high effect
7	2015-03-20	B-tea wate	13.772133	100.500098	1073.954	High effect
8	2015-03-20	C-pra a tide	13.763545	100.494025	1086.199	High effect
1	2015-03-15	A-thanomnon	13.841949	100.491073	809.4	Intermediate effect
11	2015-03-25	A-thanomnon	13.841949	100.491073	621.678	Intermediate effect
6	2015-03-20	A-thanomnon	13.841949	100.491073	527.203	Low effect

(15 rows)

Fig. 6.15 The results of classification of Total Dissolved Solid (TDS): The result showed the value, effect class and information of points (2 last left column).

id	ndate	location	latitude	longitude	turbidity	effect
4	2015-03-15	D-si praya	13.728406	100.513178	512.9	Very high effect
5	2015-03-15	E-krungtap bridge	13.692558	100.491907	313.96	Very high effect
6	2015-03-20	A-thanomnon	13.841949	100.491073	86.82	Very high effect
7	2015-03-20	B-tea wate	13.772133	100.500098	64.38	Very high effect
8	2015-03-20	C-pra a tide	13.763545	100.494025	104.95	Very high effect
9	2015-03-20	D-si praya	13.728406	100.513178	71.48	Very high effect
10	2015-03-20	E-krungtap bridge	13.692558	100.491907	52.59	Very high effect
11	2015-03-25	A-thanomnon	13.841949	100.491073	54.676	Very high effect
12	2015-03-25	B-tea wate	13.772133	100.500098	135.74	Very high effect
14	2015-03-25	D-si praya	13.728406	100.513178	74.94	Very high effect
13	2015-03-25	C-pra a tide	13.763545	100.494025	47.58	High effect
1	2015-03-15	A-thanomnon	13.841949	100.491073	30.98	Intermediate effect
3	2015-03-15	C-pra a tide	13.763545	100.494025	37.266	Intermediate effect
2	2015-03-15	B-tea wate	13.772133	100.500098	24.141	Low effect
15	2015-03-25	E-krungtap bridge	13.692558	100.491907	18.33	Completely safe

(15 rows)

Fig. 6.16 The results of classification of Turbidity: The result showed the value, effect class and information of points (2 last left column).

6.2.3 The critical contaminate detection and classification of multiple-parameter waters by a real-time warning system

This subsection discusses the notification or warning system when applying the trigger to rSPA. The system will work by detecting the value of the data. When the input values of the data are more than the standard threshold, then the system classifies the effect class, and after that the system sends output in terms of information of the point, value, and effect class. The results of the system are shown as:

- The Conductivity at E point (Krungtap bridge on March 25, 2015), the value is 4122 at a very high effect. The results in detail are shown in Figure 6.17.
- The Dissolved Oxygen (DO) at E point (Krungtap bridge on March 25, 2015), the value is 1.695 at a very high effect. The results in detail are shown in Figure 6.18.
- The Salinity did not give a notification or warning because the input value of the data was less than the standard threshold. The results in detail are shown in Figure 6.19.
- The Total Dissolved Solid (TDS) at E point (Krungtap bridge on March 25, 2015), the value is 5572.634 at a very high effect. The results in detail are shown in Figure 6.21.
- The Turbidity at D point (Si Phraya on March 25, 2015), the value is 74.94 at a very high effect. The results in detail are shown in Figure 6.20.

```
 ndate      | location           | latitude | longitude | conductivity | effect
------------+--------------------+----------+-----------+--------------+----------------
2015-03-25 | E-krungtab bridge | 13.692558| 100.491907|          4122|Very high effect
(1 rows)
```

Fig. 6.17 The real-time notification system of Conductivity: The result showed the notification of parameter when the value more than the standard threshold in part of value, effect class and information of points.

```
   ndate    |      location      | latitude | longitude | dissolvedoxygen |    effect
------------+--------------------+----------+-----------+-----------------+----------------
 2015-03-25| E-krungtab bridge| 13.692558| 100.491907|            1.695|Very high effect
(1 rows)
```

Fig. 6.18 The real-time notification system of Dissolved Oxygen (DO): The result showed the notification of parameter when the value more than the standard threshold in part of value, effect class and information of points.

```
 id | ndate | location | latitude | longitude | salinity
----+-------+----------+----------+-----------+----------
(0 rows)
```

Fig. 6.19 The real-time notification system of Salinity: The result showed the notification of parameter no data when the value less than the standard threshold in part of value, effect class and information of points.

```
   ndate    | location           | latitude | longitude | turbidity |    effect
------------+--------------------+--------- +-----------+-----------+---------
(0 rows)
```

Fig. 6.20 The real-time notification system of Total Dissolved Solid (TDS): The result shown the notification of parameter no data when the value less than standard.

```
   ndate   |       location       | latitude | longitude |    TDS    |    effect
-----------+----------------------+----------+-----------+-----------+---------
(0 rows)
```

Fig. 6.21 The real-time notification system of Turbidity: The result showed the notification of parameter no data when the value less than the standard.

6.3 Multi-dimensional water-quality and semantic space creation

The multi-dimensional analysis is a promising approach to a new interpretation in environments by the value information and language information regarding intellectual activities in various environments and their meanings to society. This section presents a new analysis system with semantic computing for environments in water-quality areas by integrating the fundamentally important parameters of water quality to create new meaning for society. The multi-water-parameter analysis in a multi-dimensional space is important for current research issues in some water-quality research fields, which are based on the values and meanings of each parameter for obtaining of the meaningful words in the contexts of agriculture, aquatic life, fish, drinking, industry, and irrigation. The multi-dimensional semantic space is significantly utilized for various interpretations that relate to the water quality. In this section, we have presented the current situation of river water-quality at Surabaya city, Indonesia by creating a multi-dimension semantic space and finding of semantics (word) in the water quality area. The principal of this section is in the multi-dimension semantic space for water-quality parameters.

6.3.1 The Procedure of pollutant-environmental variable and utilized water design

This subsection surveys the river area, describes of the river area, and sets the sampling points. The physical characteristics of a water source are indicative of water quality. From the results of studying the river characteristics, the general environment of the river can be obtained. For the survey results at the Ngagel, Jagir, and Surabaya rivers, which are important rivers in Surabaya city, the rivers have been used as a source of water for industry, transportation, and municipal services. The river was contaminated by pollutants from pollution sources such as municipal waste, industry, and is site of waste disposal.

In addition to this experimental study in the summer season, the general environment of the rivers, the physical characteristics of the water flow, show a high concentration of pollutants, and the color of the water body is a green, yellow, light brown, dark brown, dark red, rainbow, gray, and black color. The description of the color of a river is below.

- The color of the water is green in Jagir B and C point (the cause of green colors is a plankton plant in the river).

- The yellow and light brown occur in Surabaya A, Ngagel A, and Jagir A point (the cause of yellow and brown color are algae as Dinoflagellates; Ceratium furca).
- The dark brown or dark red color is in Surabaya B, Ngagel B, and Jagir A point (the cause of dark brown or dark red color is a sediment, soil, and sludge).
- The rainbow color is in Ngagel C points (the cause of rainbow colors is an oil on the surface of the water).
- The gray and/or black color is in Surabaya C points (the cause of the gray and or black colors are waste disposal, mineral sediment, or/and sludge from natural or/and mining events which then flow into the water body).

The hydraulic characteristics of the river water flow are low velocity and a high level when the water gate is open. The average velocity of the water is 1.90 to 2.24 meter/second. The water level of the surface water is 0.40 to 2.35 meters: Jagir Rivers is 0.4 - 1.05 meters, Ngagel Rivers is 0.3 - 2.0 meters, and Surabaya Rivers is 0.7 - 2.35 meters. The results around the riverside at Surabaya city show the pollutant sources as:

- The waste water from municipal, industrial activities, and agriculture activities
- The waste disposal besides river
- The waste oil from boat and ship
- The sediment of soil and plankton plant in water body
- The decomposition of organic and inorganic waste such as dead leaves or plants, humus, food scraps, remnant of cloth, lamp, and plastic on the surface and in the water body.

In this implementation design, there are 3 types of sampling points: (1) a reference point (1 point). (2) the sampling point (1-2 points). (3) the global flux site (1 point). Then, water quality data are sampled from different places and the pollutant level in the water resource is determined. The process of sampling the water follows the standard of ISO 5667-6 [42]. The water parameters are Temperature, a potential of hydrogen (pH), Dissolved Oxygen (DO), Conductivity, Salinity, Total Dissolved Solid (TDS), Turbidity, Oxidation-Reduction potential (ORP), and

GPS. Collecting for water quality sampling took place 1 time/week. The multi water quality checker is a Horiba sensor U-52G model. From the analyzed results the critical point was found to be point 6 (Nagel-C) where all parameters are the highest and are shown in Figure 6.22 - 6.25.

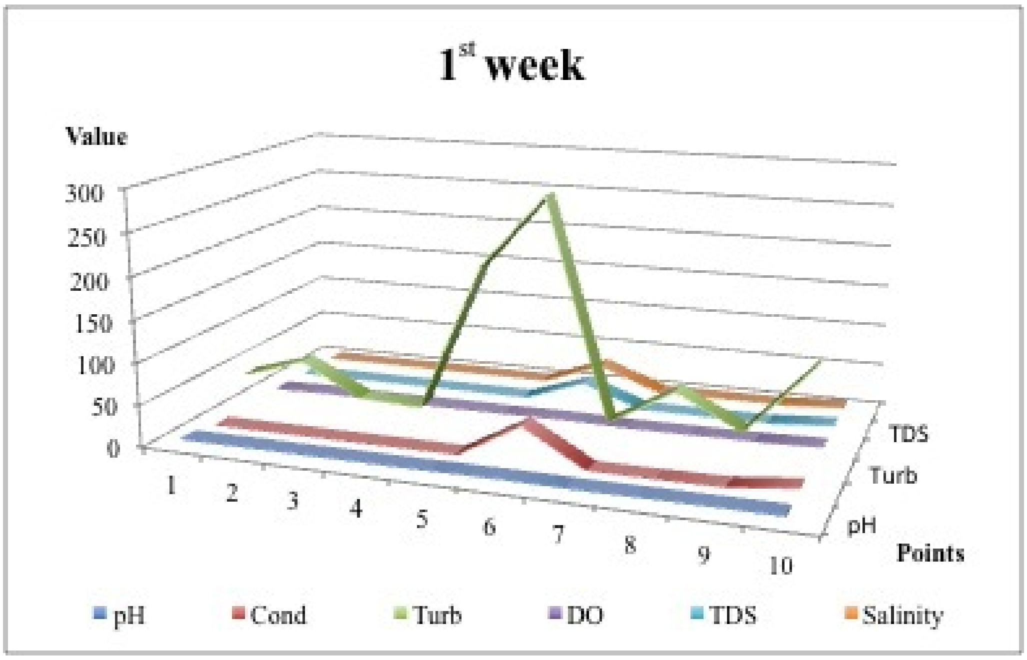


Fig. 6.22 The river water-quality (1^{st} week).

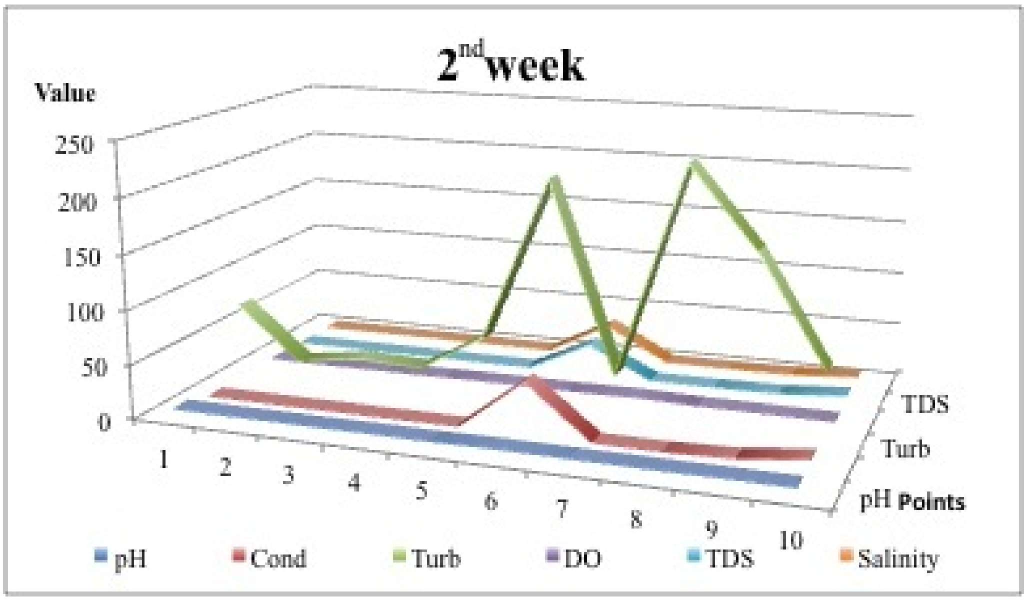


Fig. 6.23 The river water-quality (2^{nd} week).

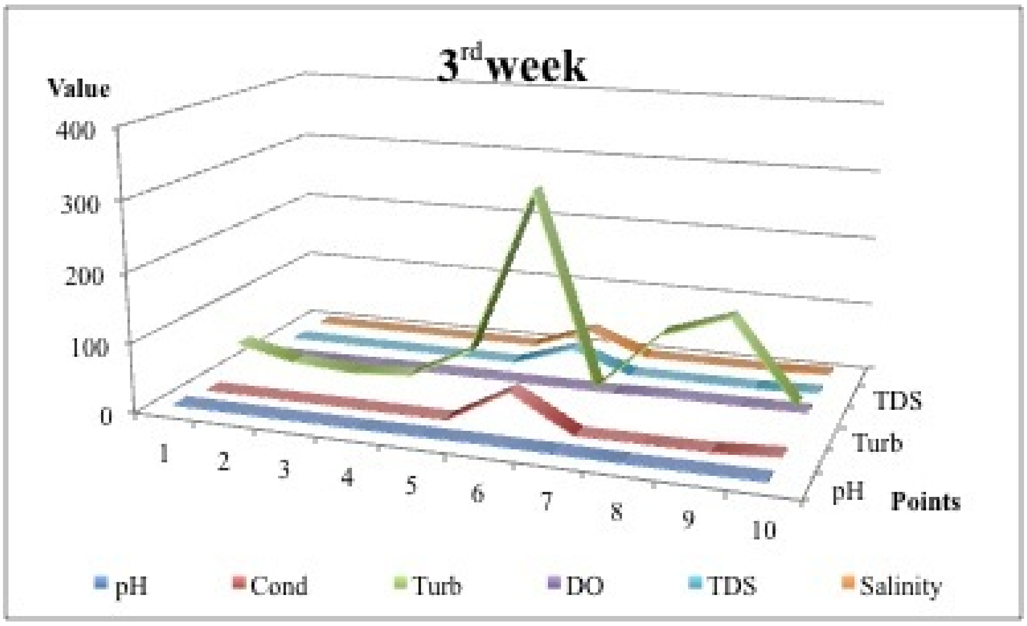


Fig. 6.24 The river water-quality (3^{rd} week).

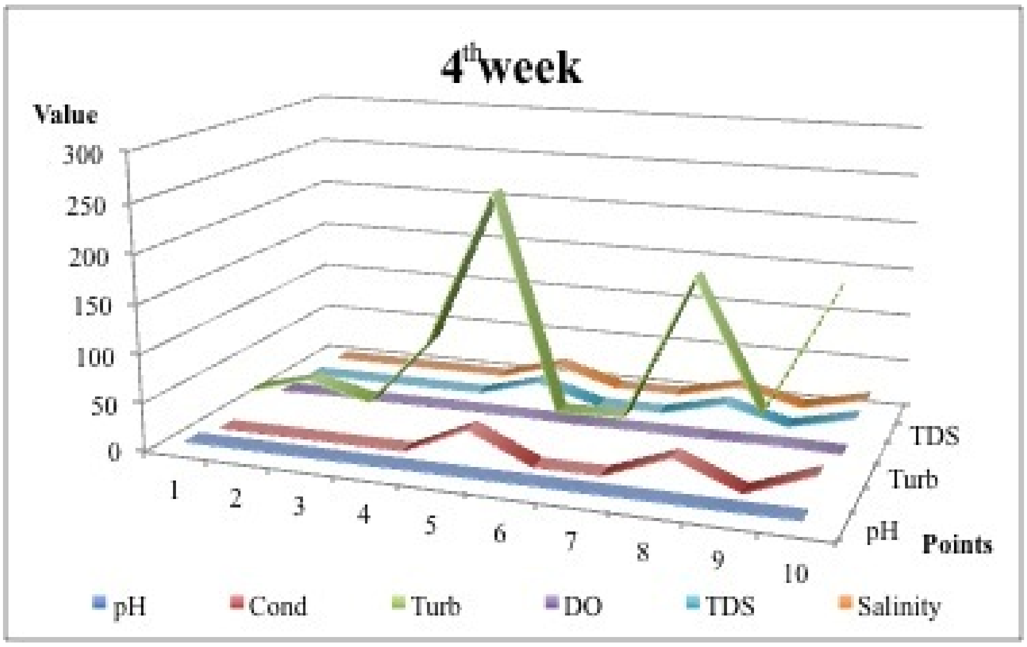


Fig. 6.25 The river water-quality (4^{th} week).

6.3.2 The Procedure of multi-dimensional space creation

In this subsection, the system design in to construct the target groups, the important river water-quality parameters for each target group, the relationship between parameters, and the effect of the parameter. In this step, designing the target group from water utilization is as follows.

- Agriculture: designing the parameters of Conductivity, Salinity, and Total Dissolved Solid (TDS).
- Aquatic life: designing the parameter of Dissolved Oxygen (DO).
- Drinking: designing the parameters of the potential of hydrogen (pH), Total Dissolved Solid (TDS), and Turbidity.
- Fish: designing the parameter of the potential of hydrogen (pH).
- Irrigation: designing the parameters of Conductivity, Salinity, and Total Dissolved Solid (TDS).
- Industry: designing the parameters of potential of hydrogen (pH), Conductivity, and Total Dissolved Solid (TDS).

After all, the design has taken place, a multi water-quality parameter semantic computing space in the 6 dimensions Conductivity, Dissolved Oxygen (DO), pH, Salinity, Total Dissolved Solid (TDS), and Turbidity was created. The meaning of the multi-river water-quality parameters were mapped in a semantic computing space of 6 dimensions. The meaning of the relationship between the water parameters is shown with ranging values and the output report is in semantic words. The outputs from the multi-dimensional semantic space are as follows:

- The output from multi-dimensional semantic space for agriculture: The semantic word hazard for sensitive crops is 25 points, the semantic word hazard for low tolerance crop is 1 point, the semantic word hazard for high tolerance crop is 1 point, the semantic word satisfactory for livestock and poultry is 1 point, and the semantic word hazard for poultry is 1 point. The result is shown in Figure 6.26.
- The output from multi-dimensional semantic space for aquatic life: The semantic words for all aquatic life extinction is 30 points, the semantic word hazard for aquatic life is 5 points, and the semantic word supports spawning is 1 point. The result is shown in Figure 6.27.

- The output from multi-dimensional semantic space for fish: The semantic word hazard for fish and salmon dying is 11 points, the semantic words abundant for fish are 24 points. The result is shown in Figure 6.28.
- The output from multi-dimensional semantic space for drinking: The semantic words hazard and chronic toxic for drinking are 2 points. The result is shown in Figure 6.29.
- The output from multi-dimensional semantic space for industry: The semantic words are moderate corrosive, scaling, and fouling at 16 points. The result is shown in Figure 6.30.
- The output from multi-dimensional semantic space for irrigation. The semantic words excellent for irrigation are 28 points and the semantic words hazard for irrigation are 7 points. The result is shown in Figure 6.31.

6.4 A River Heavy Metal Evaluation Index (rHMEI) and semantic space creation

In this section, the tool and processes for system analysis by creating the evaluation index and applying multi-dimensional subspace for minimized limitation is realized. The river Heavy Metal Evaluation Index (rHMEI) in river Sensing Processing Actuation process is created by using the multi-dimensional space of heavy metal substances, and applied to Pori's water resource (Finland) and evaluated for the effect of heavy metal parameters (9 parameters). The rHMEI is feasible and effective for analyzing water quality in several categories. In the implementation of the analysis system, we integrate special knowledge resources in environmental analysis and semantic computing for evaluating water quality in respect of heavy metals and interpret the numerical values for heavy metals to feature semantic wording. In terms of the specific characteristic in the heavy metal parameter, there are several methods for the aggregation of sub-indices. Applying the root mean square creates the index to analyze the water quality in water resources in the processing (P) part of the rSPA processes. The results of the first and second procedures are described below.

Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	Hazard for sensitive crop	2015-09-24	Surabaya-A	-7.301354	112.743381
2	Hazard for sensitive crop	2015-09-24	Surabaya-B	-7.305796	112.761288
3	Hazard for sensitive crop	2015-09-24	Surabaya-C	-7.297746	112.741606
4	Hazard for sensitive crop	2015-09-24	Ngagle-A	-7.299487	112.734737
5	Hazard for sensitive crop	2015-09-24	Ngagle-B	-7.263856	112.750372
6	Hazard for sensitive crop	2015-09-24	Jagis-A	-7.301354	112.743381
7	Hazard for sensitive crop	2015-09-24	Jagis-B	-7.305796	112.761288
8	Hazard for sensitive crop	2015-10-01	Surabaya-A	-7.301354	112.743381
9	Hazard for sensitive crop	2015-10-01	Surabaya-B	-7.305796	112.761288
10	Hazard for sensitive crop	2015-10-01	Surabaya-C	-7.297746	112.741606
11	Hazard for sensitive crop	2015-10-01	Ngagle-A	-7.299487	112.734737
12	Hazard for sensitive crop	2015-10-01	Ngagle-B	-7.263856	112.750372
13	Hazard for sensitive crop	2015-10-01	Jagis-A	-7.301354	112.743381
14	Hazard for sensitive crop	2015-10-01	Jagis-B	-7.305796	112.761288
15	Hazard for sensitive crop	2015-10-07	Surabaya-A	-7.301354	112.743381
16	Hazard for sensitive crop	2015-10-07	Surabaya-B	-7.305796	112.761288
17	Hazard for sensitive crop	2015-10-07	Surabaya-C	-7.297746	112.741606
18	Hazard for sensitive crop	2015-10-07	Ngagle-A	-7.299487	112.734737
19	Hazard for sensitive crop	2015-10-07	Ngagle-B	-7.263856	112.750372
20	Hazard for sensitive crop	2015-10-07	Jagis-A	-7.301354	112.743381
21	Hazard for sensitive crop	2015-10-07	Jagis-B	-7.305796	112.761288
22	Hazard for sensitive crop	2015-10-12	Surabaya-A	-7.301354	112.743381
23	Hazard for sensitive crop	2015-10-12	Ngagle-A	-7.299487	112.734737
24	Hazard for sensitive crop	2015-10-12	Ngagle-B	-7.263856	112.750372

Fig. 6.26 The semantics (word) for agriculture.

Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	All aquatic life extinetion	2015-09-24	Surabaya-A	-7.301354	112.743381
2	All aquatic life extinetion	2015-09-24	Surabaya-B	-7.305796	112.761288
3	All aquatic life extinetion	2015-09-24	Surabaya-C	-7.297746	112.741606
4	All aquatic life extinetion	2015-09-24	Ngagle-A	-7.299487	112.734737
5	All aquatic life extinetion	2015-09-24	Ngagle-B	-7.263856	112.750372
6	All aquatic life extinetion	2015-09-24	Jagis-A	-7.301354	112.743381
7	All aquatic life extinetion	2015-09-24	Jagis-B	-7.305796	112.761288
8	All aquatic life extinetion	2015-09-24	Jagis-C	-7.310150	112.783255
9	All aquatic life extinetion	2015-10-01	Surabaya-A	-7.301354	112.743381
10	All aquatic life extinetion	2015-10-01	Surabaya-B	-7.305796	112.761288
11	All aquatic life extinetion	2015-10-01	Surabaya-C	-7.297746	112.741606
12	All aquatic life extinetion	2015-10-01	Ngagle-A	-7.299487	112.734737
13	All aquatic life extinetion	2015-10-01	Ngagle-B	-7.263856	112.750372
14	All aquatic life extinetion	2015-10-01	Ngagle-C	-7.199499	112.735368
15	All aquatic life extinetion	2015-10-01	Jagis-B	-7.305796	112.761288
16	All aquatic life extinetion	2015-10-01	Jagis-C	-7.310150	112.783255
17	All aquatic life extinetion	2015-10-01	Jagis-D	-7.305158	112.806950
18	All aquatic life extinetion	2015-10-07	Surabaya-A	-7.301354	112.743381
19	All aquatic life extinetion	2015-10-07	Surabaya-B	-7.305796	112.761288
20	All aquatic life extinetion	2015-10-07	Surabaya-C	-7.297746	112.741606
21	All aquatic life extinetion	2015-10-07	Ngagle-A	-7.299487	112.734737
22	All aquatic life extinetion	2015-10-07	Ngagle-B	-7.263856	112.750372
23	All aquatic life extinetion	2015-10-07	Ngagle-C	-7.199499	112.735368
24	All aquatic life extinetion	2015-10-07	Jagis-A	-7.301354	112.743381

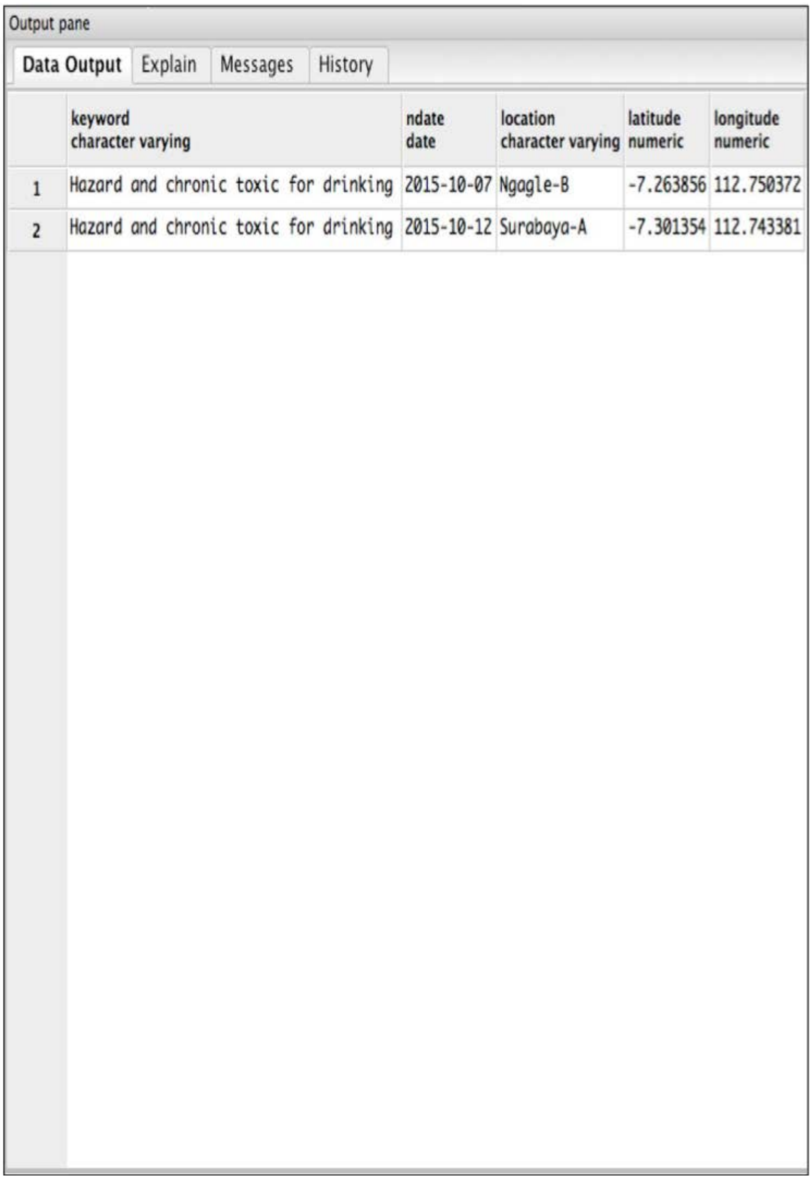
Fig. 6.27 The semantics (word) for aquatic life.

Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	Hazard for fish and salmon dying	2015-09-24	Ngagle-C	-7.199499	112.735368
2	Hazard for fish and salmon dying	2015-10-01	Ngagle-C	-7.199499	112.735368
3	Hazard for fish and salmon dying	2015-10-01	Jagis-A	-7.301354	112.743381
4	Hazard for fish and salmon dying	2015-10-07	Surabaya-A	-7.301354	112.743381
5	Hazard for fish and salmon dying	2015-10-07	Ngagle-B	-7.263856	112.750372
6	Hazard for fish and salmon dying	2015-10-07	Ngagle-C	-7.199499	112.735368
7	Hazard for fish and salmon dying	2015-10-12	Surabaya-A	-7.301354	112.743381
8	Hazard for fish and salmon dying	2015-10-12	Ngagle-A	-7.299487	112.734737
9	Hazard for fish and salmon dying	2015-10-12	Jagis-B	-7.305796	112.761288
10	Hazard for fish and salmon dying	2015-10-12	Jagis-C	-7.310150	112.783255
11	Hazard for fish and salmon dying	2015-10-12	Jagis-D	-7.305158	112.806950
12	Abundant for fish	2015-09-24	Surabaya-A	-7.301354	112.743381
13	Abundant for fish	2015-09-24	Surabaya-B	-7.305796	112.761288
14	Abundant for fish	2015-09-24	Surabaya-C	-7.297746	112.741606
15	Abundant for fish	2015-09-24	Ngagle-A	-7.299487	112.734737
16	Abundant for fish	2015-09-24	Ngagle-B	-7.263856	112.750372
17	Abundant for fish	2015-09-24	Jagis-A	-7.301354	112.743381
18	Abundant for fish	2015-09-24	Jagis-B	-7.305796	112.761288
19	Abundant for fish	2015-09-24	Jagis-C	-7.310150	112.783255
20	Abundant for fish	2015-09-24	Jagis-D	-7.305158	112.806950
21	Abundant for fish	2015-10-01	Surabaya-A	-7.301354	112.743381
22	Abundant for fish	2015-10-01	Surabaya-B	-7.305796	112.761288
23	Abundant for fish	2015-10-01	Surabaya-C	-7.297746	112.741606
24	Abundant for fish	2015-10-01	Ngagle-A	-7.299487	112.734737

Fig. 6.28 The semantics (word) for fish.


Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	Hazard and chronic toxic for drinking	2015-10-07	Ngagle-B	-7.263856	112.750372
2	Hazard and chronic toxic for drinking	2015-10-12	Surabaya-A	-7.301354	112.743381

Fig. 6.29 The semantics (word) for drinking.

Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	Moderate corrosive, scaling and fouling	2015-09-24	Jagis-C	-7.310150	112.783255
2	Moderate corrosive, scaling and fouling	2015-10-01	Surabaya-A	-7.301354	112.743381
3	Moderate corrosive, scaling and fouling	2015-10-01	Surabaya-B	-7.305796	112.761288
4	Moderate corrosive, scaling and fouling	2015-10-01	Ngagle-A	-7.299487	112.734737
5	Moderate corrosive, scaling and fouling	2015-10-01	Jagis-A	-7.301354	112.743381
6	Moderate corrosive, scaling and fouling	2015-10-01	Jagis-B	-7.305796	112.761288
7	Moderate corrosive, scaling and fouling	2015-10-07	Surabaya-A	-7.301354	112.743381
8	Moderate corrosive, scaling and fouling	2015-10-07	Surabaya-B	-7.305796	112.761288
9	Moderate corrosive, scaling and fouling	2015-10-07	Surabaya-C	-7.297746	112.741606
10	Moderate corrosive, scaling and fouling	2015-10-07	Ngagle-A	-7.299487	112.734737
11	Moderate corrosive, scaling and fouling	2015-10-07	Ngagle-B	-7.263856	112.750372
12	Moderate corrosive, scaling and fouling	2015-10-07	Jagis-A	-7.301354	112.743381
13	Moderate corrosive, scaling and fouling	2015-10-12	Surabaya-A	-7.301354	112.743381
14	Moderate corrosive, scaling and fouling	2015-10-12	Ngagle-A	-7.299487	112.734737
15	Moderate corrosive, scaling and fouling	2015-10-12	Ngagle-B	-7.263856	112.750372
16	Moderate corrosive, scaling and fouling	2015-10-12	Jagis-B	-7.305796	112.761288

Fig. 6.30 The semantics (word) for industry.

Output pane

Data Output | Explain | Messages | History

	keyword character varying	ndate date	location character varying	latitude numeric	longitude numeric
1	Excellent for irrigation	2015-09-24	Surabaya-A	-7.301354	112.743381
2	Excellent for irrigation	2015-09-24	Surabaya-B	-7.305796	112.761288
3	Excellent for irrigation	2015-09-24	Surabaya-C	-7.297746	112.741606
4	Excellent for irrigation	2015-09-24	Ngagle-A	-7.299487	112.734737
5	Excellent for irrigation	2015-09-24	Ngagle-B	-7.263856	112.750372
6	Excellent for irrigation	2015-09-24	Jagis-A	-7.301354	112.743381
7	Excellent for irrigation	2015-09-24	Jagis-B	-7.305796	112.761288
8	Excellent for irrigation	2015-10-01	Surabaya-A	-7.301354	112.743381
9	Excellent for irrigation	2015-10-01	Surabaya-B	-7.305796	112.761288
10	Excellent for irrigation	2015-10-01	Surabaya-C	-7.297746	112.741606
11	Excellent for irrigation	2015-10-01	Ngagle-A	-7.299487	112.734737
12	Excellent for irrigation	2015-10-01	Ngagle-B	-7.263856	112.750372
13	Excellent for irrigation	2015-10-01	Jagis-A	-7.301354	112.743381
14	Excellent for irrigation	2015-10-01	Jagis-B	-7.305796	112.761288
15	Excellent for irrigation	2015-10-07	Surabaya-A	-7.301354	112.743381
16	Excellent for irrigation	2015-10-07	Surabaya-B	-7.305796	112.761288
17	Excellent for irrigation	2015-10-07	Surabaya-C	-7.297746	112.741606
18	Excellent for irrigation	2015-10-07	Ngagle-A	-7.299487	112.734737
19	Excellent for irrigation	2015-10-07	Ngagle-B	-7.263856	112.750372
20	Excellent for irrigation	2015-10-07	Jagis-A	-7.301354	112.743381
21	Excellent for irrigation	2015-10-07	Jagis-B	-7.305796	112.761288
22	Excellent for irrigation	2015-10-12	Surabaya-A	-7.301354	112.743381
23	Excellent for irrigation	2015-10-12	Ngagle-A	-7.299487	112.734737
24	Excellent for irrigation	2015-10-12	Ngagle-B	-7.263856	112.750372

Fig. 6.31 The semantics (word) for irrigation.

6.4.1 The Procedure of Index Creation (rHMEI) by Using Multi-heavy metal parameters

The Heavy Metal Parameter Design for Index Creation

The Heavy Metal Parameter Design for Index Creation. The low to the high toxicity of heavy metal parameters is used in this study (9 parameters; Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc) from U.S. Geological Circular 1133 (Robert H.M., 1995) for creating the river Heavy Metal Evaluation Index (rHMEI). The specific characteristics of the heavy metal parameter for index creation shown in Table 6.1, 6.2 and 6.3 (Duruibe J.O. et al., 2007, Mung D. et al., 2014, Baigal A.T. et al., 2015, Jin H.K. et al., 2010, Thanh k. et al., 2015, John B.W. et al., 2015 and Hongxia S. et al., 2016) [62–68]. The water-quality definitions in terms of heavy metal parametersare summarized in Table 6.1 - 6.3.

Table 6.1 The heavy metal parameter design for index creation.

Parameter	Symbol	Definition
Arsenic	As	- Arsenic is the most toxic substance and appears in tree allotropic form. In the environment, arsenic can be found naturally on the Earth in small concentrations that occurs in soil, minerals, and due human activities such as mining, melting, and the copper-lead-zinc producing industry, and then it goes into water. An effect of arsenic in water is chronic toxicity for aquatic life (arsenic (III) compound blocks enzymatic processes). Exposure to inorganic arsenic can cause various health effects such as skin disturbances, cancer, declined resistance to infections, and damage to DNA. The concentration of this parameter is reported in μg/L.
Cadmium	Cd	- Cadmium is a high toxicity metal at low concentration exposure and a carcinogen group 1. Cadmium can be found in several industry activities such as paints, manufacturing of batteries, and agriculture activities. Exposure to a high concentration can cause cancer. The concentration of this parameter is reported in μg/L.
Chromium	Cr	- Chromium is one of the toxic metals in water resources. In the environment, chromium can be found in the Earth's crust and due to human activities. For the environmental effects, chromium

Table 6.2 The heavy metal parameter design for index creation (*Cont*.).

Parameter	Symbol	Definition
		can be transported and absorbed by sludge. A high concentration can be extremely dangerous to aquatic life and vegetation. Exposure to a high value can cause skin disturbances and accumulation in the kidneys. The concentration of this parameter is reported in μg/L.
Copper	Cu	- Copper is one of 129 priority pollutants listed by the EPA. In the environment, copper can be found in the Earth's crust and due to human activities. For the environmental effects, copper can be extremely dangerous to aquatic life and vegetation when it is dissolved in the water. Exposure to a high concentration can cause acute-chronic health effects, cancer hazard, and reproductive hazard. The concentration of this parameter is reported in mg/L.
Iron	Fe	- Iron is one of heavy metals in water resource areas. In the environment, chromium can be found in the Earth's crust and due to human activities. Exposure to a high concentration can cause conjunctivitis, choroiditis, and retinitis (if it contacts and remains in the tissues). The concentration of this parameter is reported in mg/L.
Lead	Pb	- Lead is one of four metals that have not only the most hazardous effects on human health but also cause several effects and serious damage. In the environment, lead occurs naturally and mainly from human activities such as car engines burning. The environmental effects of lead in water is accumulation in the aquatic organisms and soil, small concentrations cause effects for shellfish, fish, and phytoplankton. Exposure to lead causes a rise in blood pressure and disruption of biosynthesis. The concentration of this parameter is reported in mg/L.
Mercury	Hg	- Mercury is one of the widespread environment toxic molecular pollutant with severe alternations in body tissue and it also causes a wide range of human effects. Exposure to mercury affects human carcinogens and damages the nervous system (determined by EPA). The nervous system is very sensitive to all of the forms of mercury because it can damage brain function,

Table 6.3 The heavy metal parameter design for index creation (*Cont*.).

Parameter	Symbol	Definition
		kidneys, lung, nausea, vomiting, diarrhea, and blood (blood pressure increase) or heart rate, skin rashes, and eyes. The concentration of this parameter is reported in μg/L.
Nickel	Ni	- Nickel is one of four substances that are ferromagnetic at room temperature (25 ^{0}C). In the environment, nickel is discovered in small amounts and occurs by combining with sulfur. For the environmental effects, exposure to a high nickel concentration in water can diminish the growth rates of algae, and is hazardous to microorganisms and aquatic plants. It can cause skin damage, allergic reactions, destroy the development of organisms. The concentration of this parameter is reported in μg/L.
Zinc	Zn	- Zinc is a fairly active element. It dissolves in both acids and alkalis. In the environment, zinc occurs naturally and mainly from human activities such as car engines. The environmental effect of lead in water is accumulation in the aquatic organisms and soil. A small concentration can cause damage to shellfish, fish, and phytoplankton. Exposure to zinc can cause loss of hair, skin lesions, skin rashes, and sore throat. The concentration of this parameter is reported in mg/L.

From the different heavy metals toxic substances are naturally occurred and produced in human activities and reflecting effects for a living organism and persistent environmental contaminants as stable oxidation states. In comparing with the mathematics tools with rHMEI calculation in the water quality fields shown in Table 6.4. The finding to previous studies made an advantageous effect because it(this calculating with rHMEI) can decrease the eclipsing region, which is a problem in the case of nonlinear function making the resulting error values from an ideal situation.

Table 6.4 The comparison of several methods and our method.

Aggregation function	Relate research	Increasing scale indices	Decreasing scale indices
Weighted linear sum	-Water Quality Index (WQI) by Fabiano D.S.S. et al. (2008) [21] -Water Quality Index (WQI) by Summiya N. et al. (2014) [23] -Heavy metal pollution Index (HPI) by Mona H.M. et al. (2014) [69]	Eclipsing and no ambiguity	Eclipsing and no ambiguity
Linear sum	- Metal Index (MI) by Mohamed E.G. et al. (2014) [70] - Pollution Index (PI) by Mohamed E.G. et al. (2014) [70]	No eclipsing and ambiguity	Eclipsing and no ambiguity
Root sum power	- Pollution load Index (PLI) by Amirhossein P. et al. (2015) [71]	Eclipsing and no ambiguity	Eclipsing and no ambiguity
Root Mean square	- This study	Minimized eclipsing and ambiguity as n approch ∞	Eclipsing and no ambiguity

6.4.2 The Procedure of the Data Analyze by rHMEI on rSPA Processes

This study applies the rHMEI as a processing part on rSPA processes by using PostgreSQL. The rHMEI for Aquatic life, Livestock and Wildlife, Irrigation, Industry, and Estuary Basic water context was computed on using the guidelines of the standard in the water quality resource of each category (FAO, 1985) [33], (CCME, 1995) [72], (UNECE, 1994) [73], and (WHO, 1989) [74].

The result of feature wording as an actuation on rSPA found that the process executed feature word processing by detecting rHMEI value in the range of parameters in the heavy metal of each context:

- The feature word of Aquatic life found the safe for aquatic life in 128 notifications and threshold toxic for aquatic life in 43 notifications.
- The feature word of Irrigation found the excellent for irrigation in 142 notifications and hazard for irrigation in 29 notifications.
- The feature word of Estuary and harbor basin water found all of the notifications in Pori's water resource shown Optimum for estuary and harbor basin water.
- The feature word of Livestock and Wildlife found the satisfactory for livestock and poultry in 149 notifications and threshold toxic for livestock and poultry in 22 notifications.
- The feature word of Industry found the optimum for industrial process in 170 notifications and Unfit, high corrosive, scaling and fouling for Industrial process in 1 notification.

The result details are shown in Figure 6.32.

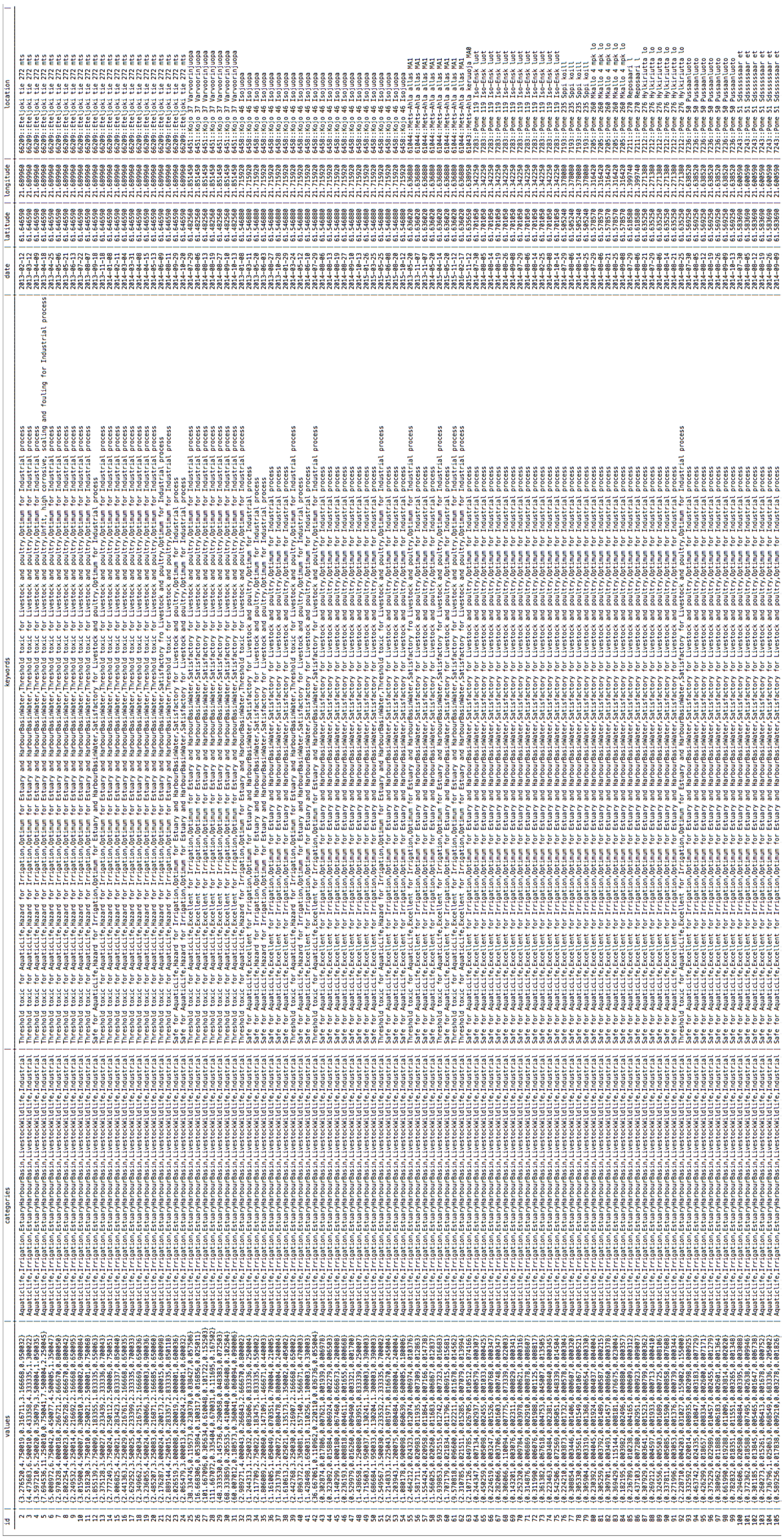


Fig. 6.32 The feature word of aquatic life, irrigation, estuary and harbor basin water, livestock and wildlife, and industrialization.

6.5 Semantic-ordering functions

This section presents the progress of the rSPA process by realization of the SPA concept and multi-dimensional semantic space created for single and multiple water quality-parameters from spatial dynamics of global water resources. The processing function included semantic computing and semantic-ordering on single and multiple water-quality-parameter values. For global analysis, water-quality observant data were collected from significant water resources located in Hawaii (USA), Pori (Finland), Riga (Latvia), and Vientiane (Laos) from March to September 2016. For local analysis, water-quality open data were collected from significant points along the Chaophraya river located in Bangkok, Nontha buri, Samut Prakan, SIng buri, Nakhon Sawan, Chai Nat, Phra Nakhon Si Ayutthaya, Pathum Thani, Ang Thong (Thailand) from 2012 to September 2014. The ranking and finding of semantics (word) in the water quality area used the semantic-ordering function, a multi water-parameters map on multi-dimensional semantic space, and visualization on 5D World map System, which is shown in Figure 6.33.

6.5.1 Experimental results of Water-quality Analysis System with Semantic-ordering functions on Single parameter for Global analysis

Using the results from the sampled water quality data, we have analyzed the water-quality with semantic-ordering functions on a single parameter at several points. The analysis process was divided into (1) Increasing parameters (such as Conductivity, Total dissolved Solid (TDS), etc.), which were analyzed from the lowest to the highest concentration as a result of the best to the worst water quality. (2) Decreasing parameters (such as Dissolved Oxygen (DO)). The analyzed parameters were reduced to a single parameter in 4 important parameters:

- The results of water-quality with semantic-ordering functions by Conductivity parameter. From the results of semantic ordering, to explore the critical levels of water-quality sanitation and hygiene intervention in low effect were detected at Daugaw river points a, b, c (Riga, Latvia), and L-kemira Oyj-2 (Pori, Finland). For the first ranking of the conductivity parameter was Kokemäenjoki river point B (Pori, Finland) on June 19, 2016, showing the levels of water-quality sanitation and hygiene intervention are completely safe for the water resource. Second-ranking of the conductivity parameter was Manoa river point c (Hawaii, USA) on March 25, 2016, and it showed the levels of water-quality sanitation are completely safe for the water resource. From the table on the third row to sixty-six row ranking of conductivity parameter was Kokemäenjoki river (Pori, Finland), Nam ngam river (Vientiane, Laos), and Alwai river, (Hawaii, USA) during summer time (May 26 - July 11, 2016) which showed the levels of water-quality sanitation and hygiene intervention are completely safe for the water resources. The result is shown in Figures 6.38 and 6.34

- The results of water-quality with semantic-ordering functions by Dissolved Oxygen parameter. From the results of semantic ordering, the critical levels of water-quality sanitation and hygiene intervention as a high effect were detected at Kokemäenjoki river point E, F, G (Pori, Finland), and Nam ngam river point B (Vientiane, Laos). For the first row ranking on the table, the dissolved oxygen parameter at Manoa river point c (Hawaii, USA) on March 25, 2016, and it showed the levels of water-quality sanitation and hygiene intervention in completely safe for water resource. From the table in second row to twenty-six row ranking, it dissolved oxygen parameter at Nuuanu river point A on March 24, 2016, Alawai river point D, E, F, G, I, J, N, K, L, M, N and O (Hawaii, USA), Kokemäenjoki river point A, B, D, E, F and G (Pori, Finland) on May 26 - July 11, 2016 and Lielupe river (Riga, Latvia) on June 2, 2016, and those showed the levels of water-quality sanitation and hygiene intervention are completely safe for the water resource. From the table in twenty-seven row to eighty row ranking of dissolved oxygen parameter were Kokemäenjoki river several points (Pori, Finland) on May 26, July (4 and 11), 2016, Daugava river (Riga, Latvia), Nam lik river, Mekong (Vientiane, Laos), and those showed the levels of water-quality sanitation and hygiene intervention in low of effect and intermediate effect for water resource. The result is shown in Figures 6.39 and 6.35.

- The results of water-quality with semantic-ordering functions by Total Dissolved Solid parameter. From the results of semantic ordering, the exploring to the critical levels of water-quality sanitation and hygiene intervention in a very high effect were detected at Nuuanu river points A and B, Alawai point E, F, J, K, L, M and O (Hawaii, USA). For the first ranking of total dissolved solid parameter at Kokemäenjoki river point B (Pori, Finland) on June 9, 2016, and it showed the levels of water-quality sanitation and hygiene intervention are completely safe for the water resource. From the table in the second row to seventy row ranking of total dissolved solid parameter at Manoa river point C (Hawaii, USA) on March 24 - 25, 2016, Kokemäenjokiriver point A, B, C, D, E, F, G, H, Boliden Harjavalta- 1, 2 (Pori, Finland) on May 26 - July 11, 2016, Lielupe river, Daugava river (Riga, Latvia) on June 2, 2016, Mekong river and Nam ngam river (Vientiane, Laos),and it showed the levels of water-quality sanitation and hygiene intervention are completely safe for the water resource. The result is shown in Figure 6.40 and 6.36

- The results of water-quality with semantic-ordering functions by Turbidity parameter. From the results of semantic ordering, the critical levels of water-quality sanitation and hygiene intervention in very high effect are detected at Kokemäenjoki river point A (Pori, Finland), Alawai point D and F (Hawaii, USA), and Nam lik river point E (Vientiane, Laos). From the table for the first row ranking of turbidity parameter at Daugava river point A (Riga, Latvia) on June 2, 2016, and it showed the levels of water-quality sanitation and hygiene intervention are completely safe for water resource. From the table in second row to sixty-four row ranking of turbidity parameter at Alawai river point E, G, H, K, L, M, N and O (Hawaii, USA) on March 26 -27, 2016, Kokemäenjoki river (Pori, Finland) point A, B, C, D, E, G and F on May 26 - July 11, 2016, Lielupe river and Daugava point C (Riga, Latvia) on June 2, 2016, and it showed the levels of water-quality sanitation and hygiene intervention are completely safe for water resource. The result is shown in Figure 6.41 and 6.37.

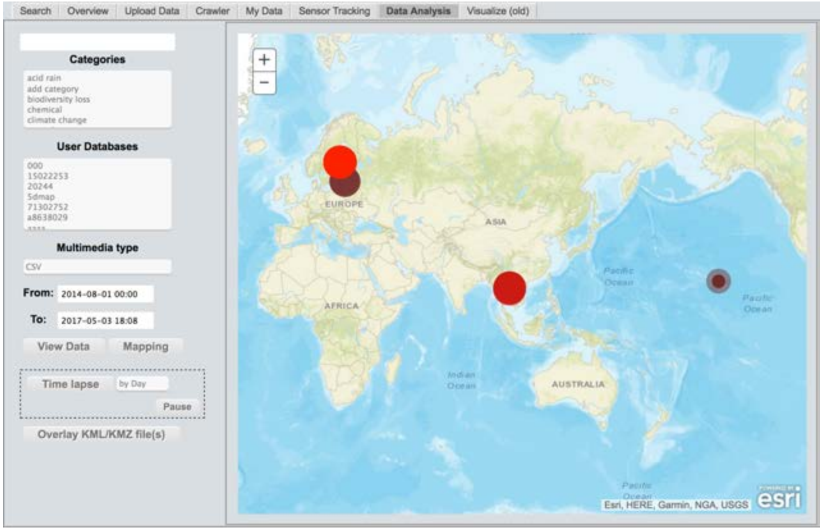


Fig. 6.33 The results of semantics word of the water-quality parameter with semantic-ordering functions on 5D World Map System (Query: water-quality parameter, Semantic ordering: by levels of water-quality sanitation and hygiene intervention).

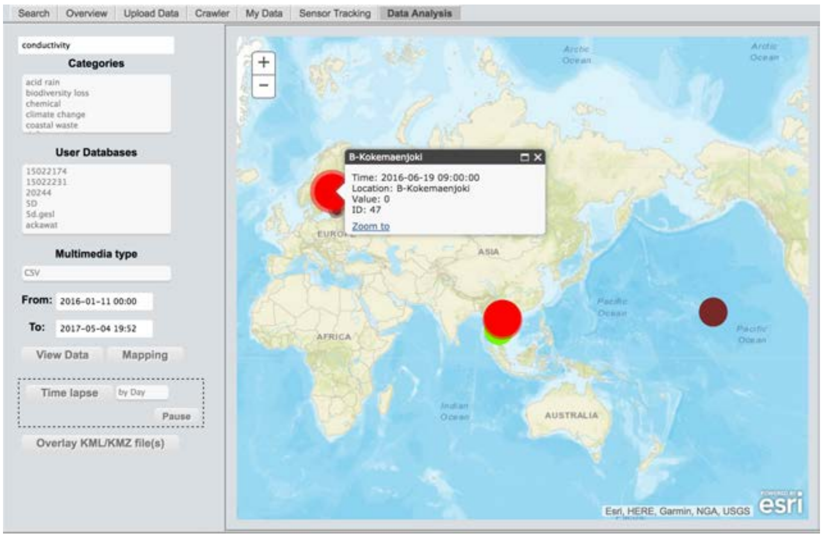


Fig. 6.34 The results of semantics word of Conductivity parameter with semantic-ordering functions on single parameter on 5D World Map System (Query: Conductivity, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

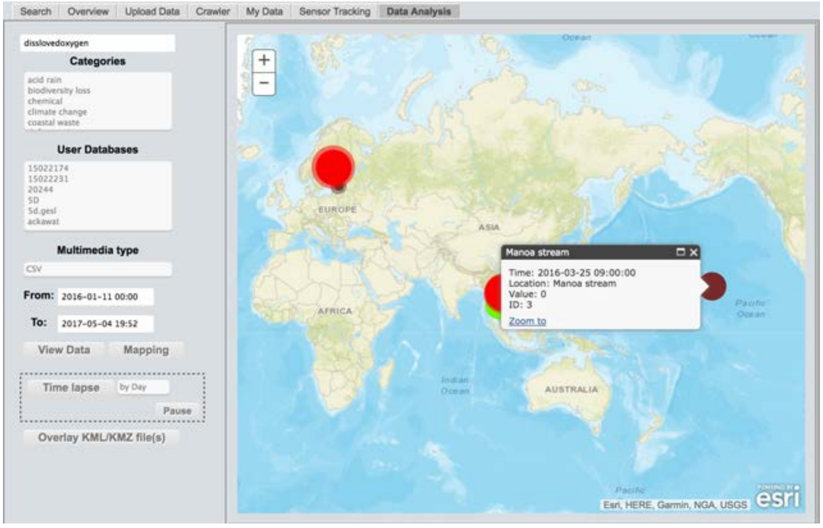


Fig. 6.35 The results of semantics word of Dissolved Oxygen (DO) parameter with semantic-ordering functions on single parameter on 5D World Map System (Query: Dissolved Oxygen, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

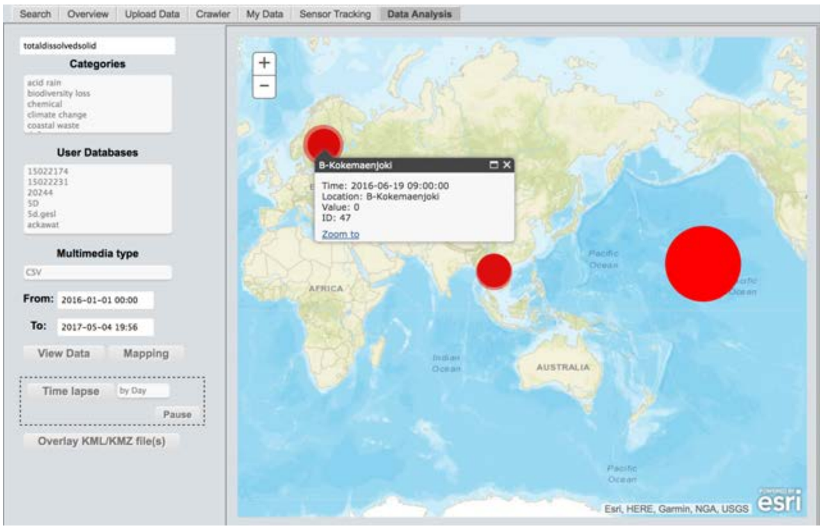


Fig. 6.36 The results of semantics word of Total Dissolved Solid (TDS) parameter with semantic-ordering functions on single parameter on 5D World Map System (Query: Total Dissolved Solid, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

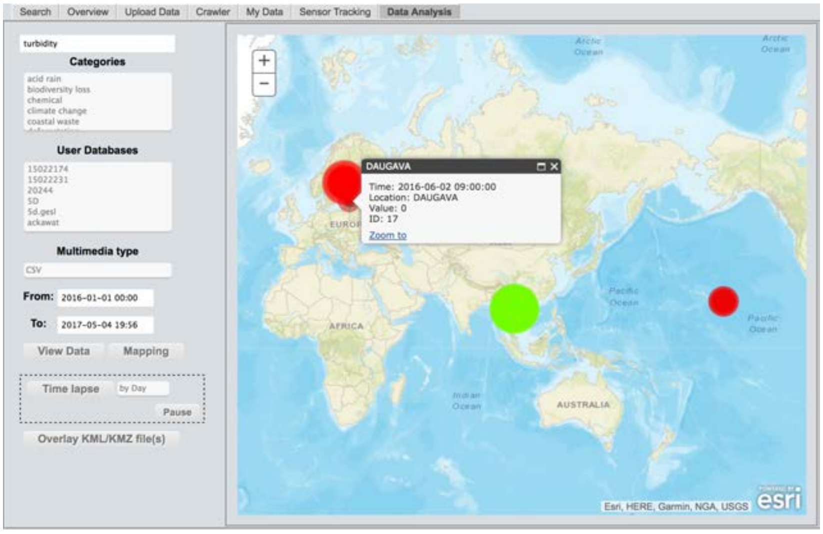


Fig. 6.37 The results of semantics word of Turbidity parameter with semantic-ordering functions on single parameter on 5D World Map System (Query: Turbidity, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

6.5.2 Experimental results of Water-quality Analysis System with Semantic-ordering functions on Multiple parameters for Global analysis

As the result from sampling water quality data, this study has analyzed the water-quality with semantic-ordering functions on multiple parameters at several points. The analysis analyzed from the lowest to the highest concentration in a result of the best to the worst water-quality. In the parameter analysis by using multiple parameters in 6 contexts:

- The results of water-quality with semantic-ordering functions for the context of agriculture. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as suddenly toxic for agriculture was detected at Nuuanu river point B (Hawaii, USA). For the critical levels of health and hygiene impact attributable to water quality in unfit for agriculture were detected at Nuuanu river point A, Alawai river point D, E, F, I, J, K, L, N, M and O (Hawaii, USA). The critical levels of health and hygiene impact attributable to water quality as the hazard for the sensitive crop were detected at L-kemira Oyj-2 (Pori, Finland). For the first ranking is Manoa river point c (Hawaii, USA) and it showed to the excellent for agriculture. From the table in second row to sixth-sever row

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semanticordering	meaning	conductivity	ndate	location	latitude	longitude
1	Completety Safe	0	2016-06-19	B-Kokemaenjoki	61.493654	21.827547
2	Completety Safe	17.26666667	2016-03-25	C-Manoa ST	21.311147	-157.808813
3	Completety Safe	56.94736842	2016-05-30	G-Kokemaenjoki	61.498453	21.783121
4	Completety Safe	81.3	2016-05-26	C-Kokemaenjoki	61.492496	21.810902
5	Completety Safe	81.65	2016-05-26	G-Kokemaenjoki	61.498453	21.783121
6	Completety Safe	85.25	2016-05-26	E-Kokemaenjoki	61.492974	21.794521
7	Completety Safe	87.725	2016-05-26	B-Kokemaenjoki	61.493654	21.827547
8	Completety Safe	87.85	2016-05-26	H-Kokemaenjoki	61.490005	21.781944
9	Completety Safe	88.3	2016-05-26	D-Kokemaenjoki	61.491615	21.801848
10	Completety Safe	91	2016-05-30	E-Kokemaenjoki	61.492974	21.794521
11	Completety Safe	91.1	2016-07-11	C-Kokemaenjoki	61.492496	21.810902
12	Completety Safe	91.95238095	2016-05-26	A-Kokemaenjoki	61.491747	21.837152
13	Completety Safe	92.23809524	2016-05-30	D-Kokemaenjoki	61.491615	21.801848
14	Completety Safe	93.25	2016-05-30	H-Kokemaenjoki	61.490005	21.781944
15	Completety Safe	93.95	2016-06-13	C-Kokemaenjoki	61.492496	21.810902
16	Completety Safe	94	2016-06-19	F-Kokemaenjoki	61.496545	21.788986
17	Completety Safe	94.15	2016-05-30	C-Kokemaenjoki	61.492496	21.810902
18	Completety Safe	94.25	2016-07-11	D-Kokemaenjoki	61.491615	21.801848
19	Completety Safe	94.55	2016-06-19	G-Kokemaenjoki	61.498453	21.783121
20	Completety Safe	94.6	2016-06-27	F-Kokemaenjoki	61.496545	21.788986
21	Completety Safe	95	2016-06-19	D-Kokemaenjoki	61.491615	21.801848
22	Completety Safe	95.90909091	2016-05-30	F-Kokemaenjoki	61.496545	21.788986
23	Completety Safe	96.05	2016-06-13	A-Kokemaenjoki	61.491747	21.837152
24	Completety Safe	96.09090909	2016-07-11	G-Kokemaenjoki	61.498453	21.783121
25	Completety Safe	96.1	2016-07-11	B-Kokemaenjoki	61.493654	21.827547
26	Completety Safe	96.3	2016-06-13	D-Kokemaenjoki	61.491615	21.801848
27	Completety Safe	96.40909091	2016-06-13	E-Kokemaenjoki	61.492974	21.794521
28	Completety Safe	96.45	2016-06-19	C-Kokemaenjoki	61.492496	21.810902
29	Completety Safe	96.57894737	2016-06-19	H-Kokemaenjoki	61.490005	21.781944
30	Completety Safe	96.65	2016-07-11	F-Kokemaenjoki	61.496545	21.788986
31	Completety Safe	96.7	2016-07-11	A-Kokemaenjoki	61.491747	21.837152
32	Completety Safe	97.1	2016-06-19	E-Kokemaenjoki	61.492974	21.794521
33	Completety Safe	97.15625	2016-05-30	B-Kokemaenjoki	61.493654	21.827547
34	Completety Safe	97.19047619	2016-06-13	G-Kokemaenjoki	61.498453	21.783121
35	Completety Safe	97.63157895	2016-07-11	E-Kokemaenjoki	61.492974	21.794521
36	Completety Safe	97.71428571	2016-07-11	H-Kokemaenjoki	61.490005	21.781944
37	Completety Safe	98.58333333	2016-06-13	F-Kokemaenjoki	61.496545	21.788986
38	Completety Safe	99.25	2016-07-04	E-Kokemaenjoki	61.492974	21.794521
39	Completety Safe	99.84615385	2016-06-13	B-Kokemaenjoki	61.493654	21.827547
40	Completety Safe	99.95	2016-06-13	H-Kokemaenjoki	61.490005	21.781944
41	Completety Safe	100.05	2016-06-19	A-Kokemaenjoki	61.491747	21.837152
42	Completety Safe	100.3	2016-06-27	C-Kokemaenjoki	61.492496	21.810902
43	Completety Safe	101.35	2016-06-27	G-Kokemaenjoki	61.498453	21.783121
44	Completety Safe	101.9	2016-06-27	D-Kokemaenjoki	61.491615	21.801848
45	Completety Safe	102.15	2016-07-04	C-Kokemaenjoki	61.492496	21.810902
46	Completety Safe	103	2016-06-27	H-Kokemaenjoki	61.490005	21.781944
46	Completety Safe	103	2016-07-04	D-Kokemaenjoki	61.491615	21.801848
48	Completety Safe	104	2016-07-04	G-Kokemaenjoki	61.498453	21.783121
48	Completety Safe	104	2016-07-04	B-Kokemaenjoki	61.493654	21.827547
50	Completety Safe	104.25	2016-06-27	E-Kokemaenjoki	61.492974	21.794521
51	Completety Safe	105	2016-07-04	F-Kokemaenjoki	61.496545	21.788986
51	Completety Safe	105	2016-07-04	H-Kokemaenjoki	61.490005	21.781944
53	Completety Safe	106.9	2016-06-27	B-Kokemaenjoki	61.493654	21.827547
54	Completety Safe	108.5	2016-06-27	A-Kokemaenjoki	61.491747	21.837152
55	Completety Safe	108.6	2016-05-26	F-Kokemaenjoki	61.496545	21.788986
56	Completety Safe	108.85	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856
57	Completety Safe	110.4	2016-07-04	A-Kokemaenjoki	61.491747	21.837152
58	Completety Safe	110.95	2016-05-30	A-Kokemaenjoki	61.491747	21.837152
59	Completety Safe	121.047619	2016-09-24	B-Nam Ngam US	18.150329	102.635581
60	Completety Safe	124.35	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626
61	Completety Safe	131.6666667	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526
62	Completety Safe	135.5454545	2016-09-25	D-Nam Ngam DS	18.52493	102.513324
63	Completety Safe	139.3157895	2016-09-24	C-Nam Ngam MS	18.368835	102.571367
64	Completety Safe	147.0526316	2016-09-25	F-Nam Lik DS	18.539164	102.51056
65	Completety Safe	150.7	2016-09-25	E-Nam Lik US	18.590006	102.491119
66	Completety Safe	213.1052632	2016-09-24	A-Mekong	17.907442	102.616652
67	Low effect	266.3	2016-06-02	B-Daugava MS	56.914538	24.167233
68	Low effect	270	2016-06-02	C-Daugava DS	56.937357	24.114167
69	Low effect	274.05	2016-06-02	A-Daugava US	56.91348	24.169145
70	Low effect	364.7619048	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344

(stdin):

Fig. 6.38 The results of semantics word of Conductivity parameter with semantic-ordering functions on single parameter (Query: Conductivity, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

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semanticordering	meaning	dissolvedoxygen	ndate	location	latitude	longitude
1	Completely safe	18.59	2016-03-25	C-Manoa ST	21.311147	-157.808813
2	Completely safe	16.92285714	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818
3	Completely safe	14.3835	2016-03-27	N-Alawai	21.28756	-157.843219
4	Completely safe	12.5065	2016-03-26	H-Alawai	21.283046	-157.827202
5	Completely safe	12.07190476	2016-03-27	L-Alawai	21.288718	-157.834047
6	Completely safe	11.454	2016-03-27	M-Alawai	21.287627	-157.83978
7	Completely safe	11.43952381	2016-03-27	K-Alawai	21.287292	-157.8321
8	Completely safe	11.27833333	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874
9	Completely safe	11.18619048	2016-03-27	J-Alawai	21.28593	-157.83054
10	Completely safe	10.81421053	2016-03-27	0-Alawai	21.284561	-157.839613
11	Completely safe	10.69363636	2016-03-27	I-Alawai	21.283438	-157.82764
12	Completely safe	10.38857143	2016-03-27	G-Alawai	21.280087	-157.823755
13	Completely safe	10.08047619	2016-03-27	E-Alawai	21.277997	-157.821242
14	Completely safe	9.084285714	2016-03-27	F-Alawai	21.277616	-157.81996
15	Completely safe	8.7065	2016-06-13	A-Kokemaenjoki	61.491747	21.837152
16	Completely safe	8.34675	2016-05-26	B-Kokemaenjoki	61.493654	21.827547
17	Completely safe	8.1725	2016-06-19	A-Kokemaenjoki	61.491747	21.837152
18	Completely safe	8.062105263	2016-06-02	LIELUPE	56.973479	23.861068
19	Completely safe	7.8885	2016-03-27	D-Alawai	21.274992	-157.817526
20	Completely safe	7.862	2016-05-26	E-Kokemaenjoki	61.492974	21.794521
21	Completely safe	7.83	2016-05-26	F-Kokemaenjoki	61.496545	21.788986
22	Completely safe	7.804	2016-06-19	B-Kokemaenjoki	61.493654	21.827547
23	Completely safe	7.751	2016-05-26	G-Kokemaenjoki	61.498453	21.783121
24	Completely safe	7.724	2016-05-30	H-Kokemaenjoki	61.490005	21.781944
25	Completely safe	7.6435	2016-05-26	D-Kokemaenjoki	61.491615	21.801848
26	Completely safe	7.5955	2016-07-11	A-Kokemaenjoki	61.491747	21.837152
27	Low effect	7.428	2016-07-11	D-Kokemaenjoki	61.491615	21.801848
28	Low effect	7.4275	2016-05-26	C-Kokemaenjoki	61.492496	21.810902
29	Low effect	7.389047619	2016-05-26	A-Kokemaenjoki	61.491747	21.837152
30	Low effect	7.379	2016-07-04	A-Kokemaenjoki	61.491747	21.837152
31	Low effect	7.352	2016-05-26	H-Kokemaenjoki	61.490005	21.781944
32	Low effect	7.307	2016-06-27	F-Kokemaenjoki	61.496545	21.788986
32	Low effect	7.307	2016-06-27	G-Kokemaenjoki	61.498453	21.783121
34	Low effect	7.184	2016-06-27	A-Kokemaenjoki	61.491747	21.837152
35	Low effect	7.0535	2016-05-30	A-Kokemaenjoki	61.491747	21.837152
36	Low effect	6.912727273	2016-07-11	G-Kokemaenjoki	61.498453	21.783121
37	Low effect	6.880526316	2016-05-30	G-Kokemaenjoki	61.498453	21.783121
38	Low effect	6.8005	2016-06-02	B-Daugava MS	56.914538	24.167233
39	Low effect	6.705	2016-06-13	H-Kokemaenjoki	61.490005	21.781944
40	Low effect	6.700454545	2016-05-30	F-Kokemaenjoki	61.496545	21.788986
41	Low effect	6.6505	2016-07-04	B-Kokemaenjoki	61.493654	21.827547
42	Low effect	6.6455	2016-06-13	C-Kokemaenjoki	61.492496	21.810902
43	Low effect	6.588	2016-06-27	B-Kokemaenjoki	61.493654	21.827547
44	Low effect	6.5465	2016-06-19	D-Kokemaenjoki	61.491615	21.801848
45	Low effect	6.546	2016-07-11	B-Kokemaenjoki	61.493654	21.827547
46	Low effect	6.542	2016-09-25	E-Nam Lik US	18.590006	102.491119
47	Low effect	6.4871875	2016-05-30	B-Kokemaenjoki	61.493654	21.827547
48	Low effect	6.431428571	2016-05-30	E-Kokemaenjoki	61.492974	21.794521
49	Low effect	6.413	2016-06-13	D-Kokemaenjoki	61.491615	21.801848
50	Low effect	6.39	2016-09-24	A-Mekong	17.907442	102.616652
51	Low effect	6.358461538	2016-06-13	B-Kokemaenjoki	61.493654	21.827547
52	Low effect	6.348947368	2016-06-19	H-Kokemaenjoki	61.490005	21.781944
53	Low effect	6.347619048	2016-07-04	H-Kokemaenjoki	61.490005	21.781944
54	Low effect	6.346	2016-07-11	C-Kokemaenjoki	61.492496	21.810902
55	Low effect	6.25	2016-07-04	D-Kokemaenjoki	61.491615	21.801848
56	Low effect	6.2355	2016-06-02	A-Daugava US	56.91348	24.169145
57	Low effect	6.159473684	2016-09-25	F-Nam Lik DS	18.539164	102.51056
58	Low effect	6.056190476	2016-05-30	D-Kokemaenjoki	61.491615	21.801848
59	Intermediate effect	5.92875	2016-06-13	F-Kokemaenjoki	61.496545	21.788986
60	Intermediate effect	5.8585	2016-05-30	C-Kokemaenjoki	61.492496	21.810902
61	Intermediate effect	5.752	2016-06-27	D-Kokemaenjoki	61.491615	21.801848
62	Intermediate effect	5.743	2016-06-19	C-Kokemaenjoki	61.492496	21.810902
63	Intermediate effect	5.732	2016-06-27	C-Kokemaenjoki	61.492496	21.810902
64	Intermediate effect	5.7155	2016-07-04	C-Kokemaenjoki	61.492496	21.810902
65	Intermediate effect	5.568095238	2016-07-11	H-Kokemaenjoki	61.490005	21.781944
66	Intermediate effect	5.507857143	2016-06-19	F-Kokemaenjoki	61.496545	21.788986
67	Intermediate effect	5.424210526	2016-07-11	E-Kokemaenjoki	61.492974	21.794521
68	Intermediate effect	5.407	2016-06-02	C-Daugava DS	56.937357	24.114167
69	Intermediate effect	5.375	2016-06-19	E-Kokemaenjoki	61.492974	21.794521
70	Intermediate effect	5.3035	2016-06-19	G-Kokemaenjoki	61.498453	21.783121
71	Intermediate effect	5.284	2016-07-04	E-Kokemaenjoki	61.492974	21.794521
72	Intermediate effect	5.185789474	2016-09-24	C-Nam Ngam MS	18.368835	102.571367
73	Intermediate effect	5.138181818	2016-06-13	E-Kokemaenjoki	61.492974	21.794521
74	Intermediate effect	5.042777778	2016-06-27	H-Kokemaenjoki	61.490005	21.781944
75	High effect	4.982857143	2016-06-13	G-Kokemaenjoki	61.498453	21.783121
76	High effect	4.9615	2016-07-11	F-Kokemaenjoki	61.496545	21.788986
77	High effect	4.924	2016-07-04	F-Kokemaenjoki	61.496545	21.788986
78	High effect	4.818571429	2016-09-24	B-Nam Ngam US	18.150329	102.635581
79	High effect	4.814545455	2016-07-04	G-Kokemaenjoki	61.498453	21.783121
80	High effect	4.725	2016-06-27	E-Kokemaenjoki	61.492974	21.794521

(stdin):

Fig. 6.39 The results of semantics word of Dissolved Oxygen (DO) parameter with semantic-ordering functions on single parameter (Query: Dissolved Oxygen, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

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semanticordering	meaning	totaldissolvedsolid	ndate	location	latitude	longitude
1	Completely safe	0	2016-06-19	B-Kokemaenjoki	61.493654	21.827547
2	Completely safe	11.26666667	2016-03-25	C-Manoa ST	21.311147	-157.808813
3	Completely safe	37.21052632	2016-05-30	G-Kokemaenjoki	61.498453	21.783121
4	Completely safe	53.05	2016-05-26	C-Kokemaenjoki	61.492496	21.810902
4	Completely safe	53.05	2016-05-26	G-Kokemaenjoki	61.498453	21.783121
6	Completely safe	55.35	2016-05-26	E-Kokemaenjoki	61.492974	21.794521
7	Completely safe	56.975	2016-05-26	B-Kokemaenjoki	61.493654	21.827547
8	Completely safe	57	2016-05-26	H-Kokemaenjoki	61.490005	21.781944
9	Completely safe	57.35	2016-05-26	D-Kokemaenjoki	61.491615	21.801848
10	Completely safe	59	2016-05-30	E-Kokemaenjoki	61.492974	21.794521
11	Completely safe	59.1	2016-07-11	C-Kokemaenjoki	61.492496	21.810902
12	Completely safe	59.95238095	2016-05-26	A-Kokemaenjoki	61.491747	21.837152
13	Completely safe	60.04761905	2016-05-30	D-Kokemaenjoki	61.491615	21.801848
14	Completely safe	60.65	2016-05-30	H-Kokemaenjoki	61.490005	21.781944
15	Completely safe	61	2016-06-19	F-Kokemaenjoki	61.496545	21.788986
16	Completely safe	61.05	2016-07-11	D-Kokemaenjoki	61.491615	21.801848
16	Completely safe	61.05	2016-05-30	C-Kokemaenjoki	61.492496	21.810902
18	Completely safe	61.15	2016-06-13	C-Kokemaenjoki	61.492496	21.810902
19	Completely safe	61.3	2016-06-27	F-Kokemaenjoki	61.496545	21.788986
20	Completely safe	61.5	2016-06-19	G-Kokemaenjoki	61.498453	21.783121
21	Completely safe	62	2016-06-19	D-Kokemaenjoki	61.491615	21.801848
22	Completely safe	62.05	2016-06-13	A-Kokemaenjoki	61.491747	21.837152
23	Completely safe	62.3	2016-07-11	B-Kokemaenjoki	61.493654	21.827547
24	Completely safe	62.36363636	2016-05-30	F-Kokemaenjoki	61.496545	21.788986
25	Completely safe	62.5	2016-07-11	G-Kokemaenjoki	61.498453	21.783121
26	Completely safe	62.7	2016-06-19	C-Kokemaenjoki	61.492496	21.810902
27	Completely safe	62.75	2016-07-11	F-Kokemaenjoki	61.496545	21.788986
28	Completely safe	62.8	2016-07-11	A-Kokemaenjoki	61.491747	21.837152
29	Completely safe	63	2016-06-19	H-Kokemaenjoki	61.490005	21.781944
29	Completely safe	63	2016-06-13	D-Kokemaenjoki	61.491615	21.801848
29	Completely safe	63	2016-06-13	E-Kokemaenjoki	61.492974	21.794521
32	Completely safe	63.05	2016-06-19	E-Kokemaenjoki	61.492974	21.794521
33	Completely safe	63.14285714	2016-06-13	G-Kokemaenjoki	61.498453	21.783121
34	Completely safe	63.25	2016-05-30	B-Kokemaenjoki	61.493654	21.827547
35	Completely safe	63.42105263	2016-07-11	E-Kokemaenjoki	61.492974	21.794521
36	Completely safe	63.42857143	2016-07-11	H-Kokemaenjoki	61.490005	21.781944
37	Completely safe	63.875	2016-06-13	F-Kokemaenjoki	61.496545	21.788986
38	Completely safe	64.4	2016-07-04	E-Kokemaenjoki	61.492974	21.794521
39	Completely safe	64.80769231	2016-06-13	B-Kokemaenjoki	61.493654	21.827547
40	Completely safe	65	2016-06-13	H-Kokemaenjoki	61.490005	21.781944
40	Completely safe	65	2016-06-19	A-Kokemaenjoki	61.491747	21.837152
42	Completely safe	65.15	2016-06-27	C-Kokemaenjoki	61.492496	21.810902
43	Completely safe	65.95	2016-06-27	D-Kokemaenjoki	61.491615	21.801848
44	Completely safe	66	2016-06-27	G-Kokemaenjoki	61.498453	21.783121
45	Completely safe	66.4	2016-07-04	C-Kokemaenjoki	61.492496	21.810902
46	Completely safe	67	2016-07-04	D-Kokemaenjoki	61.491615	21.801848
46	Completely safe	67	2016-07-04	B-Kokemaenjoki	61.493654	21.827547
46	Completely safe	67	2016-06-27	H-Kokemaenjoki	61.490005	21.781944
49	Completely safe	68	2016-07-04	F-Kokemaenjoki	61.496545	21.788986
49	Completely safe	68	2016-06-27	E-Kokemaenjoki	61.492974	21.794521
49	Completely safe	68	2016-07-04	G-Kokemaenjoki	61.498453	21.783121
52	Completely safe	68.14285714	2016-07-04	H-Kokemaenjoki	61.490005	21.781944
53	Completely safe	69.4	2016-06-27	B-Kokemaenjoki	61.493654	21.827547
54	Completely safe	70.6	2016-06-27	A-Kokemaenjoki	61.491747	21.837152
55	Completely safe	70.7	2016-05-26	F-Kokemaenjoki	61.496545	21.788986
56	Completely safe	70.9	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856
57	Completely safe	71.75	2016-07-04	A-Kokemaenjoki	61.491747	21.837152
58	Completely safe	72.1	2016-05-30	A-Kokemaenjoki	61.491747	21.837152
59	Completely safe	79	2016-09-24	B-Nam Ngam US	18.150329	102.635581
60	Completely safe	81	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626
61	Completely safe	85.16666667	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526
62	Completely safe	88.09090909	2016-09-25	D-Nam Ngam DS	18.52493	102.513324
63	Completely safe	90.63157895	2016-09-24	C-Nam Ngam MS	18.368835	102.571367
64	Completely safe	96	2016-09-25	F-Nam Lik DS	18.539164	102.51056
65	Completely safe	98	2016-09-25	E-Nam Lik US	18.590006	102.491119
66	Completely safe	138.3684211	2016-09-24	A-Mekong	17.907442	102.616652
67	Completely safe	173.1	2016-06-02	B-Daugava MS	56.914538	24.167233
68	Completely safe	175.4	2016-06-02	C-Daugava DS	56.937357	24.114167
69	Completely safe	178.15	2016-06-02	A-Daugava US	56.91348	24.169145
70	Completely safe	237.0952381	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344
71	Low effect	536.1578947	2016-06-02	LIELUPE	56.973479	23.861068
72	Very high effect	1624.285714	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818
73	Very high effect	18061.90476	2016-03-27	F-Alawai	21.277616	-157.81996
74	Very high effect	18457.14286	2016-03-27	K-Alawai	21.287292	-157.8321
75	Very high effect	21276.19048	2016-03-27	L-Alawai	21.288718	-157.834047
76	Very high effect	25633.33333	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874
77	Very high effect	26323.80952	2016-03-27	J-Alawai	21.28593	-157.83054
78	Very high effect	27410	2016-03-27	M-Alawai	21.287627	-157.83978
79	Very high effect	27800	2016-03-27	E-Alawai	21.277997	-157.821242
80	Very high effect	27831.57895	2016-03-27	0-Alawai	21.284561	-157.839613

(stdin):

Fig. 6.40 The results of semantics word of Total Dissolved Solid (TDS) parameter with semantic-ordering functions on single parameter (Query: Total Dissolved Solid, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

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semanticordering	meaning	turbidity	ndate	location	latitude	longitude
1	Completely safe	0	2016-06-02	A-Daugava US	56.91348	24.169145
2	Completely safe	0.005	2016-06-02	B-Daugava MS	56.914538	24.167233
3	Completely safe	0.324210526	2016-03-27	O-Alawai	21.284561	-157.839613
4	Completely safe	0.4315	2016-07-11	C-Kokemaenjoki	61.492496	21.810902
5	Completely safe	0.858	2016-03-27	M-Alawai	21.287627	-157.83978
6	Completely safe	0.9975	2016-05-26	C-Kokemaenjoki	61.492496	21.810902
7	Completely safe	1.2045	2016-07-04	C-Kokemaenjoki	61.492496	21.810902
8	Completely safe	1.224761905	2016-03-27	L-Alawai	21.288718	-157.834047
9	Completely safe	1.464736842	2016-06-02	LIELUPE	56.973479	23.861068
10	Completely safe	2.087142857	2016-05-30	D-Kokemaenjoki	61.491615	21.801848
11	Completely safe	2.128	2016-03-27	N-Alawai	21.28756	-157.843219
12	Completely safe	2.543809524	2016-03-27	E-Alawai	21.277997	-157.821242
13	Completely safe	2.830526316	2016-05-30	G-Kokemaenjoki	61.498453	21.783121
14	Completely safe	3.214	2016-06-27	C-Kokemaenjoki	61.492496	21.810902
15	Completely safe	3.533809524	2016-03-27	G-Alawai	21.280087	-157.823755
16	Completely safe	3.820952381	2016-03-27	K-Alawai	21.287292	-157.8321
17	Completely safe	3.9075	2016-05-26	G-Kokemaenjoki	61.498453	21.783121
18	Completely safe	4.0325	2016-05-30	C-Kokemaenjoki	61.492496	21.810902
19	Completely safe	4.675	2016-06-19	A-Kokemaenjoki	61.491747	21.837152
20	Completely safe	5.015909091	2016-05-30	F-Kokemaenjoki	61.496545	21.788986
21	Completely safe	5.052	2016-07-11	B-Kokemaenjoki	61.493654	21.827547
22	Completely safe	5.646	2016-06-02	C-Daugava DS	56.937357	24.114167
23	Completely safe	5.7155	2016-06-19	C-Kokemaenjoki	61.492496	21.810902
24	Completely safe	5.736904762	2016-06-13	G-Kokemaenjoki	61.498453	21.783121
25	Completely safe	6.176818182	2016-06-13	E-Kokemaenjoki	61.492974	21.794521
26	Completely safe	6.8275	2016-07-11	D-Kokemaenjoki	61.491615	21.801848
27	Completely safe	7.079	2016-07-11	A-Kokemaenjoki	61.491747	21.837152
28	Completely safe	7.79125	2016-06-13	F-Kokemaenjoki	61.496545	21.788986
29	Completely safe	7.8845	2016-03-26	H-Alawai	21.283046	-157.827202
30	Completely safe	8.2395	2016-06-19	G-Kokemaenjoki	61.498453	21.783121
31	Completely safe	8.358846154	2016-06-13	B-Kokemaenjoki	61.493654	21.827547
32	Completely safe	8.399	2016-06-27	G-Kokemaenjoki	61.498453	21.783121
33	Completely safe	8.795909091	2016-09-25	D-Nam Ngam DS	18.52493	102.513324
34	Completely safe	8.813181818	2016-07-04	G-Kokemaenjoki	61.498453	21.783121
35	Completely safe	8.828	2016-07-04	E-Kokemaenjoki	61.492974	21.794521
36	Completely safe	8.985238095	2016-05-26	A-Kokemaenjoki	61.491747	21.837152
37	Completely safe	9.013333333	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344
38	Completely safe	9.1945	2016-06-13	H-Kokemaenjoki	61.490005	21.781944
39	Completely safe	9.342	2016-07-04	B-Kokemaenjoki	61.493654	21.827547
40	Completely safe	9.4175	2016-05-26	F-Kokemaenjoki	61.496545	21.788986
41	Completely safe	9.4845	2016-07-11	F-Kokemaenjoki	61.496545	21.788986
42	Completely safe	9.581	2016-06-27	E-Kokemaenjoki	61.492974	21.794521
43	Completely safe	9.667	2016-06-27	F-Kokemaenjoki	61.496545	21.788986
44	Completely safe	9.765789474	2016-07-11	E-Kokemaenjoki	61.492974	21.794521
45	Completely safe	9.9045	2016-05-30	A-Kokemaenjoki	61.491747	21.837152
46	Completely safe	10.0395	2016-07-04	F-Kokemaenjoki	61.496545	21.788986
47	Completely safe	10.665	2016-06-27	B-Kokemaenjoki	61.493654	21.827547
48	Completely safe	10.76555556	2016-06-27	H-Kokemaenjoki	61.490005	21.781944
49	Completely safe	10.771	2016-07-04	D-Kokemaenjoki	61.491615	21.801848
50	Completely safe	11.49333333	2016-07-11	H-Kokemaenjoki	61.490005	21.781944
51	Completely safe	11.6	2016-06-27	A-Kokemaenjoki	61.491747	21.837152
52	Completely safe	11.98095238	2016-07-04	H-Kokemaenjoki	61.490005	21.781944
53	Completely safe	12	2016-07-11	G-Kokemaenjoki	61.498453	21.783121
54	Completely safe	12.628	2016-05-26	B-Kokemaenjoki	61.493654	21.827547
55	Completely safe	13.315	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856
56	Completely safe	14.54	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626
57	Completely safe	14.54444444	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526
58	Completely safe	14.75	2016-06-19	F-Kokemaenjoki	61.496545	21.788986
59	Completely safe	16.04133333	2016-03-25	C-Manoa ST	21.311147	-157.808813
60	Completely safe	17.44	2016-06-19	E-Kokemaenjoki	61.492974	21.794521
61	Completely safe	17.747	2016-05-26	E-Kokemaenjoki	61.492974	21.794521
62	Completely safe	18.605	2016-05-26	H-Kokemaenjoki	61.490005	21.781944
63	Completely safe	19.19473684	2016-09-24	C-Nam Ngam MS	18.368835	102.571367
64	Completely safe	19.81904762	2016-03-27	J-Alawai	21.28593	-157.83054
65	Low effect	20.22863636	2016-03-27	I-Alawai	21.283438	-157.82764
66	Low effect	27.665	2016-06-27	D-Kokemaenjoki	61.491615	21.801848
67	Low effect	27.685	2016-05-30	H-Kokemaenjoki	61.490005	21.781944
68	Low effect	28.205	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818
69	Intermediate effect	30.335	2016-06-19	D-Kokemaenjoki	61.491615	21.801848
70	Intermediate effect	33.9985	2016-05-26	D-Kokemaenjoki	61.491615	21.801848
71	Intermediate effect	34.27142857	2016-09-24	B-Nam Ngam US	18.150329	102.635581
72	Intermediate effect	35.66315789	2016-09-25	F-Nam Lik DS	18.539164	102.51056
73	Intermediate effect	35.69166667	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874
74	High effect	43.935	2016-06-19	B-Kokemaenjoki	61.493654	21.827547
75	High effect	49.9790625	2016-05-30	B-Kokemaenjoki	61.493654	21.827547
76	Very high effect	52.3845	2016-03-27	D-Alawai	21.274992	-157.817526
77	Very high effect	55.4245	2016-07-04	A-Kokemaenjoki	61.491747	21.837152
78	Very high effect	66.72857143	2016-03-27	F-Alawai	21.277616	-157.81996
79	Very high effect	77.8445	2016-06-13	A-Kokemaenjoki	61.491747	21.837152
80	Very high effect	87.76	2016-09-25	E-Nam Lik US	18.590006	102.491119

(stdin):

Fig. 6.41 The results of semantics word of Turbidity parameter with semantic-ordering functions on single parameter (Query: Turbidity, Semantic ordering: by levels of water-quality sanitation and hygiene intervention (ordering by using 5 conditions: Completely safe, Low effect, Intermediate effect, High effect, and Very high effect)).

ranking were several points along at the Kokemäenjoki river point A, B, C, D, E, F, G, H, Boliden Harjavalta-2 (Pori, Finland) (Mach 26- July 11, 2016, Nam ngamriver and Nam lik river (Vientiane, Laos), and it showed excellent for agriculture. The result is shown in Figures 6.48 and 6.43.

- The results of water-quality with semantic-ordering functions for the context of aquatic life. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as Hazard for aquatic life were detected at Kokemäenjoki river points E, G and F, Boliden harjavalta-2, kemire Oyj-1 (Pori, Finland), and Nam ngam river point B (Vientiane, Laos). For the levels of health and hygiene impact attributable to water quality in supports spawning for aquatic life were detected at Kokemäenjoki river point C, D, E, F, G, H (Pori, Finland), and Daugava river point C (Riga, Latvia). For the levels of health and hygiene impact attributable to water quality points to support growth and activity for aquatic life were detected at Kokemäenjokii river (Pori, Finland) points B, C, D, E, F, G and H (May 26 - June 27, 2016), Daugava point A and B (Riga, Latvia), and Nam lik river point A and B (Vientiane, Laos). From the table in the first row to second row ranking were Alawai river point N (Hawaii, USA) point A and C (March 27, 2016) and other, it showed abundant for aquatic life. The result is shown in Figures 6.49 and 6.43.

- The results of water-quality with semantic-ordering functions for the context of drinking. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality in unfit for drinking were detected at Nam lik river point E, Mekong river point A (Vientiane, Laos), Alawai river point D, F, I, J, Nuuanu river point B (Hawaii, USA), and Kokemäenjoki river point A, B, C, D, E, F, G and H (Pori, Finland). For the levels of health and hygiene impact attributable to water quality as hazard and chronic toxic for drinking was detected at several points at Kokemäenjoki river (May 26 - July 11, 2016)(Pori, Finland), Nam Lik and Nam ngam river (Vientiane, Laos), Lielupe river and Daugava river (Riga, Latvia), and Nuuanu river, Alawai river and Manoa river (Hawaii, USA). The result is shown in Figures 6.50 and 6.44.

- The results of water-quality with semantic-ordering functions for the context of fish. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as a hazard for fish and salmon dying were detected at Alawai river point E, G, I, J, H, M and O

(Hawaii, USA) on March 3, 2016. For the levels of health and hygiene impact attributable to water quality as optimum for fish and shrimp was detected at Kokemäenjoki river point A, B, C D, E, F, G and H on May 26 - June 19, 2016 (Pori, Finland). For the levels of health and hygiene impact attributable to water quality in abundant for fish, frogs and insects was detected at several points in Kokemäenjoki river (Pori, Finland), Manoa river, Alawai river (Hawaii, USA), Nam ngam river, Nam lik river and Mekong river (Vientiane, Laos), and Daugava river and Lielupe river (Riga, Latvia). The result is shown in Figures 6.51 and 6.45.

- The results of water-quality with semantic-ordering functions for the context of industry. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality in unfit for industrial processes was detected at Alawai river point B, D, E, F, E, I, J, L, K and O (Hawaii, USA) on March 3, 2016. For the levels of health and hygiene impact attributable to water quality in slightly corrosive scaling and fouling was detected at Manoa river and Nuuanu river (Hawaii, USA) on March 24 -25, 2016, Lielupe river (Riga, Latvia),and Kokemäenjoki river point A, B, C, H and Kemira Oyj-2 on May 26 - July 11, 2016 (Pori, Finland). For the levels of health and hygiene impact attributable to water quality as optimum for industrial processes was detected at several points in Kokemäenjoki river (Pori, Finland), Daugava river (Riga, Latvia), and Nam ngam river, Namlik river and Mekong river(Vientiane, Laos). The result is shown in Figures 6.52 and 6.46.

- The results of water-quality with semantic-ordering functions for the context of irrigation. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as severe for irrigation was detected at Alawai river point E, F, J, K, L, M, N, O, Manoa river point C, and Nuuanu river point B (Hawaii, USA) on March 3, 2016. For the levels of health and hygiene impact attributable to water quality in Excellent for irrigation was detected at several points in Kokemäenjoki river on May 26 - July 11, 2016 (Pori, Finland), Lielupe river and Daugava river (Riga, Latvia), and Nam ngam river, Namlik river and Mekong river(Vientiane, Laos). The result is shown in Figures 6.53 and 6.47.

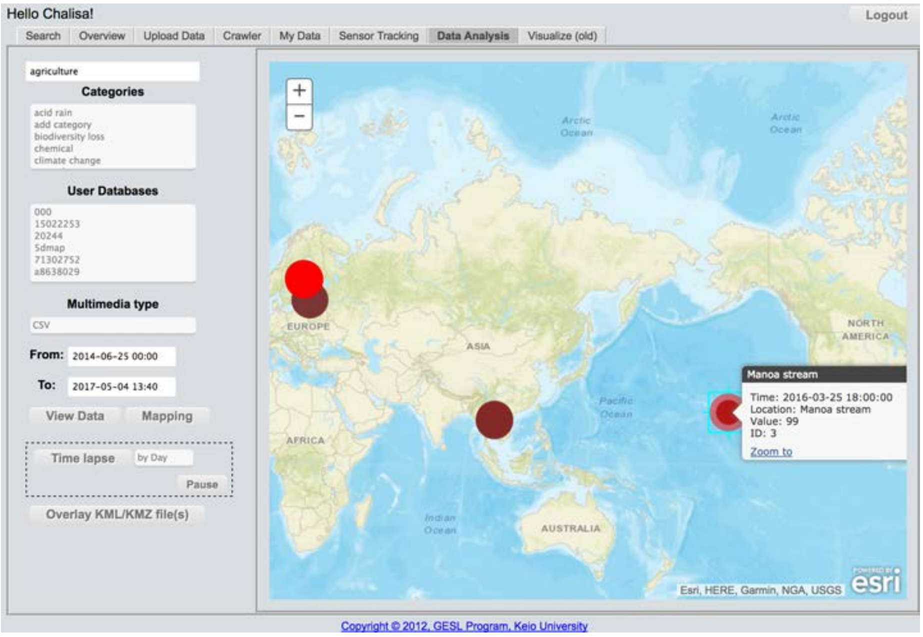

Fig. 6.42 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of agriculture on 5D World Map System (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).

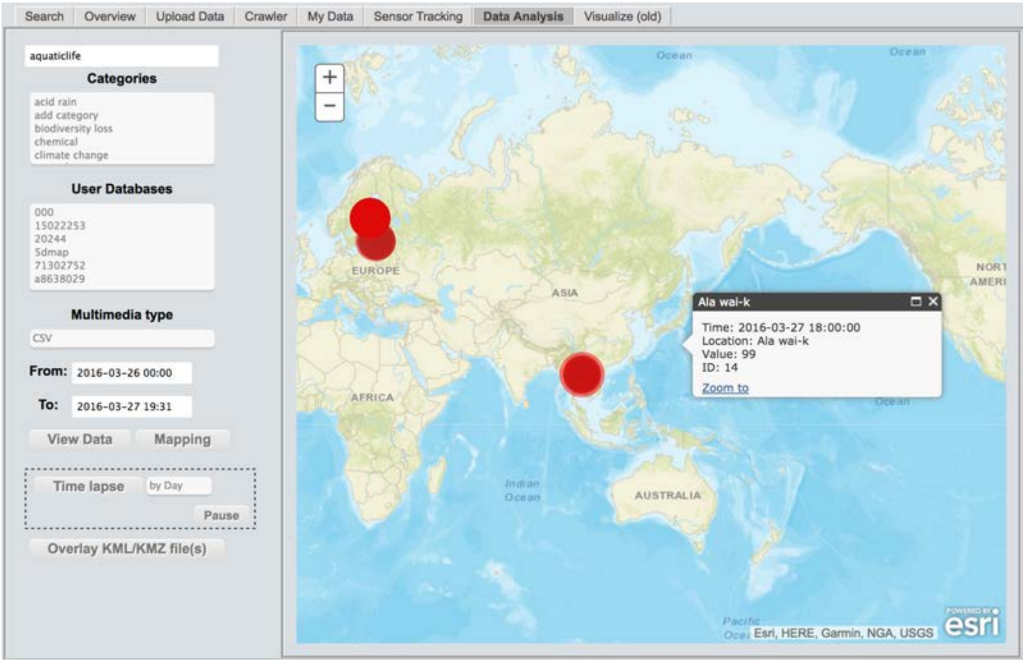

Fig. 6.43 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of aquatic life on 5D World Map System (Query: aquatic life, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, and All aquatic life extinction)).

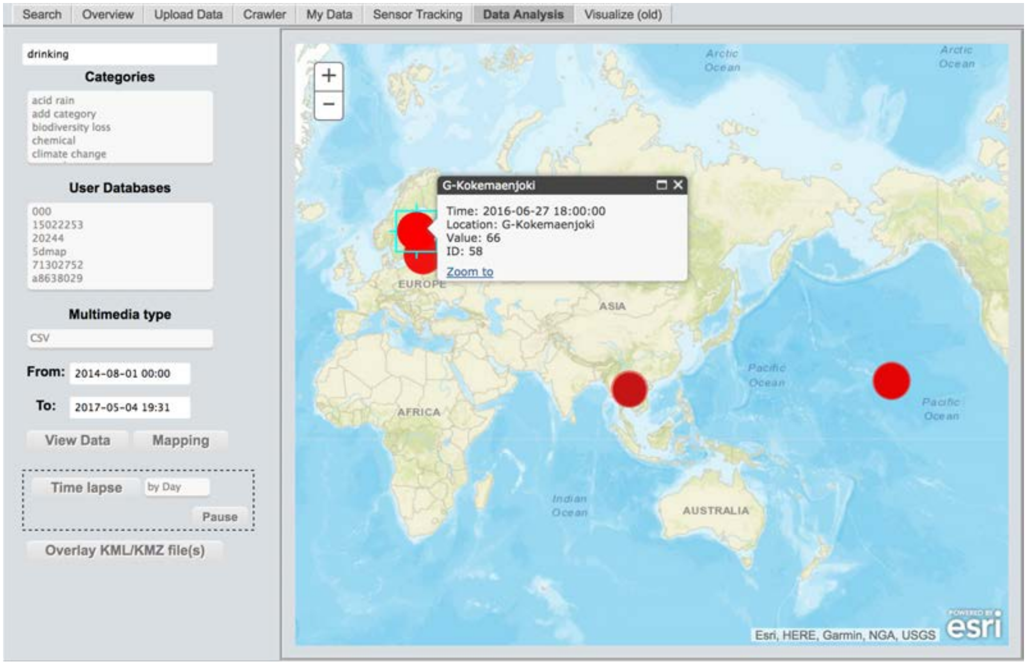

Fig. 6.44 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of drinking on 5D World Map System (Query: drinking, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Optimum for drinking, Hazard and chronic toxic for drinking, and Unfit and toxic for drinking)).

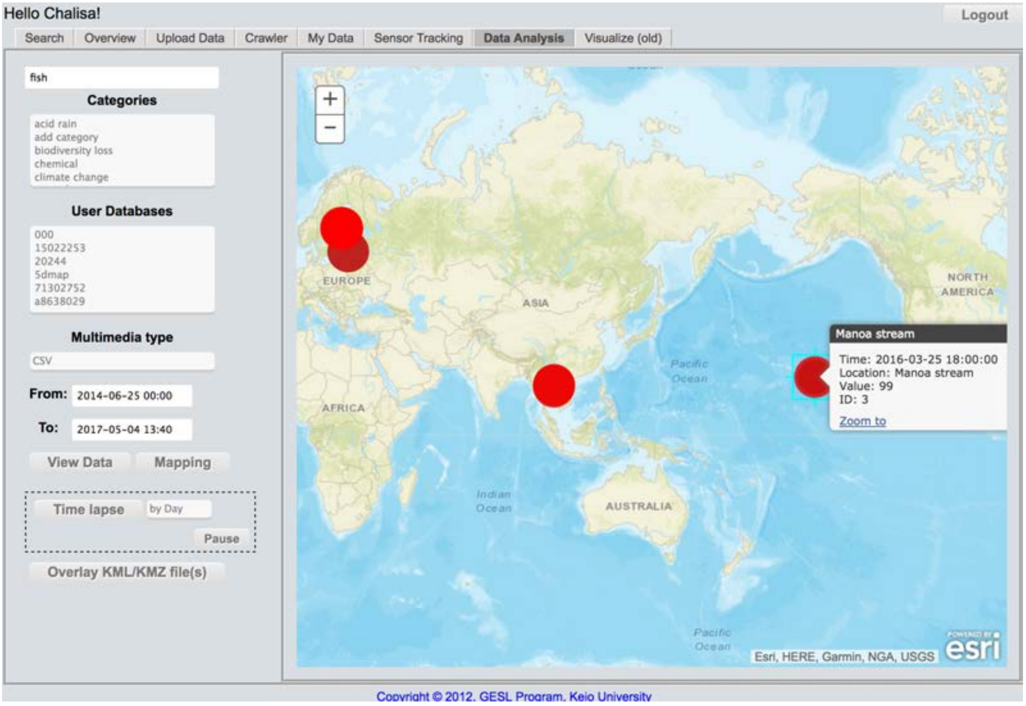

Fig. 6.45 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of fish on 5D World Map System (Query: fish, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant for fish, Optimum for fish and shrimp, Bacteria and plankton being disappear, Hazard for fish and salmon dying, and All fish extinction)).

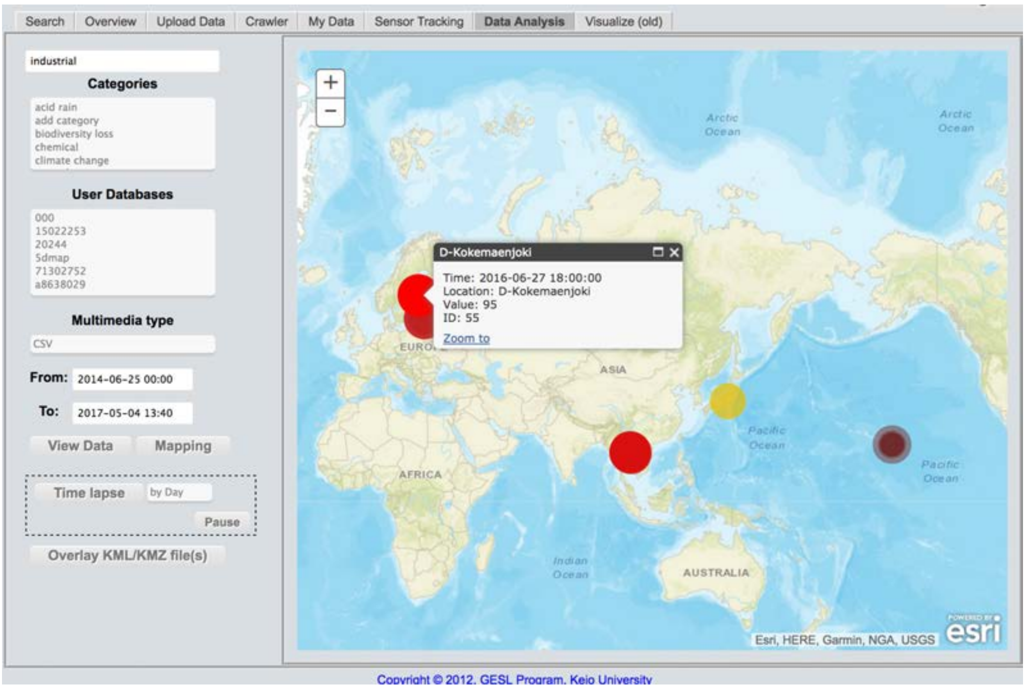

Fig. 6.46 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of industry on 5D World Map System (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).

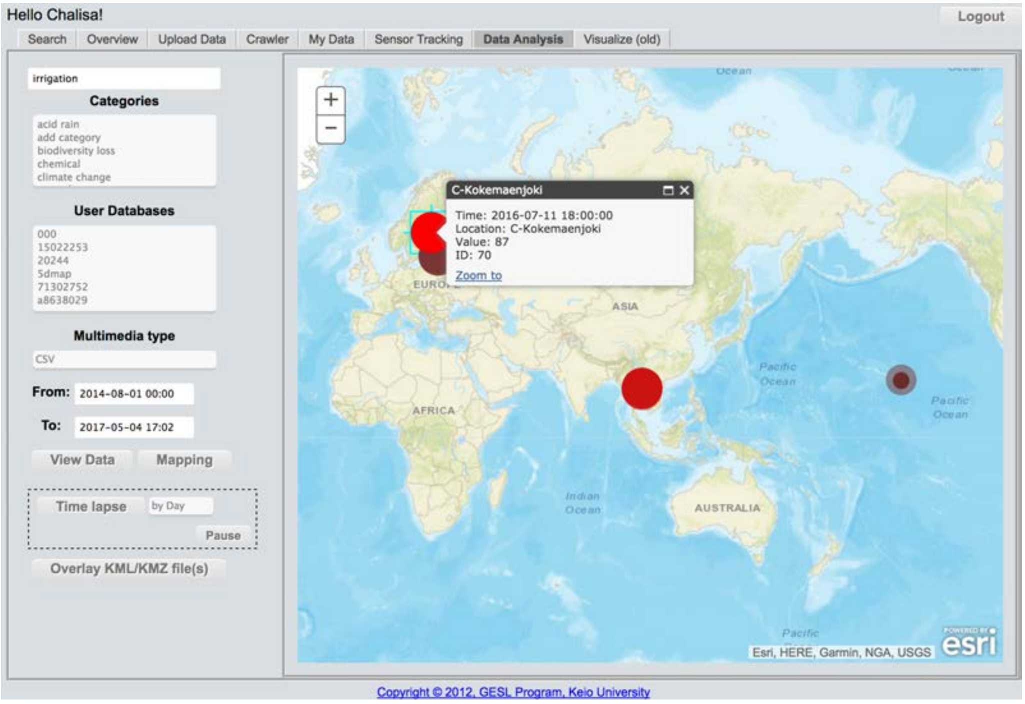

Fig. 6.47 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of irrigation on 5D World Map System (Query: irrigation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Excellent for irrigation, Moderate hazard for irrigation, and Hazard for irrigation)).

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semanticordering	factor	keyword	ndate	location	latitude	longitude	conductivity	totaldissolvedsolid	salinity
1	99.21407406	Excellent for agriculture	2016-03-25	C-Manoa ST	21.311147	-157.808813	17.26666667	11.26666667	0.006666667
2	98.01725146	Excellent for agriculture	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	56.94736842	37.21052632	0
3	97.17138889	Excellent for agriculture	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	81.3	53.05	0
4	97.16555556	Excellent for agriculture	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	81.65	53.05	0
5	97.04166667	Excellent for agriculture	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	85.25	55.35	0
6	96.95527778	Excellent for agriculture	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	87.725	56.975	0
7	96.9525	Excellent for agriculture	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	87.85	57	0
8	96.93527778	Excellent for agriculture	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	88.3	57.35	0
9	96.84444444	Excellent for agriculture	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	91	59	0
10	96.84	Excellent for agriculture	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	91.1	59.1	0
11	96.8021164	Excellent for agriculture	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	91.95238095	59.95238095	0
12	96.79470899	Excellent for agriculture	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	92.23809524	60.04761905	0
13	96.76111111	Excellent for agriculture	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	93.25	60.65	0
14	96.73888889	Excellent for agriculture	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	94	61	0
15	96.73555556	Excellent for agriculture	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	93.95	61.15	0
16	96.735	Excellent for agriculture	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	94.15	61.05	0
17	96.73333333	Excellent for agriculture	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	94.25	61.05	0
18	96.72055556	Excellent for agriculture	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	94.6	61.3	0
19	96.71583333	Excellent for agriculture	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	94.55	61.5	0
20	96.69444444	Excellent for agriculture	2016-06-19	D-Kokemaenjoki	61.491615	21.801848	95	62	0
21	96.67555556	Excellent for agriculture	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	96.05	62.05	0
22	96.66919192	Excellent for agriculture	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	95.90909091	62.36363636	0
23	96.66777778	Excellent for agriculture	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	96.1	62.3	0
24	96.66237374	Excellent for agriculture	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	96.09090909	62.5	0
25	96.65083333	Excellent for agriculture	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	96.45	62.7	0
26	96.64611111	Excellent for agriculture	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	96.65	62.75	0
27	96.645	Excellent for agriculture	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	96.3	63	0
28	96.64388889	Excellent for agriculture	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	96.7	62.8	0
29	96.64318182	Excellent for agriculture	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	96.40909091	63	0
30	96.64035088	Excellent for agriculture	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	96.57894737	63	0
31	96.63027778	Excellent for agriculture	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	97.1	63.05	0
32	96.62619048	Excellent for agriculture	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	97.19047619	63.14285714	0
33	96.62378472	Excellent for agriculture	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	97.15625	63.25	0
34	96.61111111	Excellent for agriculture	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	97.63157895	63.42105263	0
35	96.60952381	Excellent for agriculture	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	97.71428571	63.42857143	0
36	96.58263889	Excellent for agriculture	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	98.58333333	63.875	0
37	96.53568376	Excellent for agriculture	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	99.84615385	64.80769231	0
38	96.52861111	Excellent for agriculture	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	99.95	65	0
39	96.52694444	Excellent for agriculture	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	100.05	65	0
40	96.51861111	Excellent for agriculture	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	100.3	65.15	0
41	96.4775	Excellent for agriculture	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	101.35	66	0
42	96.46972222	Excellent for agriculture	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	101.9	65.95	0
43	96.45305556	Excellent for agriculture	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	102.15	66.4	0
44	96.42222222	Excellent for agriculture	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	103	67	0
44	96.42222222	Excellent for agriculture	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	103	67	0
46	96.41805556	Excellent for agriculture	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	99.25	64.4	0.005
47	96.40555556	Excellent for agriculture	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	104	67	0
48	96.37777778	Excellent for agriculture	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	104	68	0
49	96.37361111	Excellent for agriculture	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	104.25	68	0
50	96.36111111	Excellent for agriculture	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	105	68	0
51	96.35714286	Excellent for agriculture	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	105	68.14285714	0
52	96.29055556	Excellent for agriculture	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	106.9	69.4	0
53	94.75916667	Excellent for agriculture	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	110.95	72.1	0.05
54	94.63916667	Excellent for agriculture	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	110.4	71.75	0.055
55	94.55944444	Excellent for agriculture	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	108.6	70.7	0.06
56	93.86944444	Excellent for agriculture	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	108.5	70.6	0.085
57	93.5775	Excellent for agriculture	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	108.85	70.9	0.095
58	93.01031746	Excellent for agriculture	2016-09-24	B-Nam Ngam US	18.150329	102.635581	121.047619	79	0.1
59	92.89972222	Excellent for agriculture	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	124.35	81	0.1
60	92.66203704	Excellent for agriculture	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526	131.6666667	85.16666667	0.1
61	92.51616162	Excellent for agriculture	2016-09-25	D-Nam Ngam DS	18.52493	102.513324	135.5454545	88.09090909	0.1
62	92.38274854	Excellent for agriculture	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	139.3157895	90.63157895	0.1
63	92.10467836	Excellent for agriculture	2016-09-25	F-Nam Lik DS	18.539164	102.51056	147.0526316	96	0.1
64	91.98833333	Excellent for agriculture	2016-09-25	E-Nam Lik US	18.590006	102.491119	150.7	98	0.1
65	89.82690058	Excellent for agriculture	2016-09-24	A-Mekong	17.907442	102.616652	213.1052632	138.3684211	0.1
66	87.67733333	Excellent for agriculture	2016-06-02	B-Daugava MS	56.914538	24.167233	266.3	173.1	0.1
67	87.57047619	Excellent for agriculture	2016-06-02	C-Daugava DS	56.937357	24.114167	270	175.4	0.1
68	84.91156463	Hazard for sensitive crop	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	364.7619048	237.0952381	0.2
69	22.82111011	Unfit for agriculture	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818	25214.28571	1624.285714	15.37142857
70	17.86818182	Unfit for agriculture	2016-03-27	D-Alawai	21.274992	-157.817526	46480	28355	30.16
71	17.69323921	Unfit for agriculture	2016-03-27	I-Alawai	21.283438	-157.82764	45772.72727	27922.72727	29.64545455
72	17.66177399	Unfit for agriculture	2016-03-27	N-Alawai	21.28756	-157.843219	45645	27845	29.55
73	17.66071903	Unfit for agriculture	2016-03-27	O-Alawai	21.284561	-157.839613	45647.36842	27831.57895	29.58421053
74	17.64339827	Unfit for agriculture	2016-03-27	E-Alawai	21.277997	-157.821242	45571.42857	27800	29.5
75	17.49775884	Unfit for agriculture	2016-03-27	M-Alawai	21.287627	-157.83978	44985	27410	29.085
76	17.04172679	Unfit for agriculture	2016-03-27	J-Alawai	21.28593	-157.83054	43142.85714	26323.80952	27.75238095
77	14.98602092	Unfit for agriculture	2016-03-27	L-Alawai	21.288718	-157.834047	34871.42857	21276.19048	21.92857143
78	14.5452032	Unfit for agriculture	2016-03-27	K-Alawai	21.287292	-157.8321	30219.04762	18457.14286	18.71428571
79	14.46598696	Unfit for agriculture	2016-03-27	F-Alawai	21.277616	-157.81996	29161.90476	18061.90476	17.90095238
80	10.55399557	Suddenly toxic for agriculture	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	41850	25633.33333	26.74166667

(stdin)

Fig. 6.48 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of agriculture (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).

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semanticordering	factor	keyword	ndate	location	latitude	longitude	dissolvedoxygen
1	99.38817042	Abundant for aquatic life	2016-03-27	N-Alawai	21.28756	-157.843219	14.3835
2	91.60056881	Abundant for aquatic life	2016-03-26	H-Alawai	21.283046	-157.827202	12.5065
3	90.2172766	Abundant for aquatic life	2016-03-27	L-Alawai	21.288718	-157.834047	12.07190476
4	88.44680448	Abundant for aquatic life	2016-03-27	M-Alawai	21.287627	-157.83978	11.454
5	88.40780989	Abundant for aquatic life	2016-03-27	K-Alawai	21.287292	-157.8321	11.43952381
6	87.98072438	Abundant for aquatic life	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	11.27833333
7	87.74230482	Abundant for aquatic life	2016-03-27	J-Alawai	21.28593	-157.83054	11.18619048
8	86.8197431	Abundant for aquatic life	2016-03-27	0-Alawai	21.284561	-157.839613	10.81421053
9	86.53372999	Abundant for aquatic life	2016-03-27	I-Alawai	21.283438	-157.82764	10.69363636
10	85.83661418	Abundant for aquatic life	2016-03-27	G-Alawai	21.280087	-157.823755	10.38857143
11	85.1687907	Abundant for aquatic life	2016-03-27	E-Alawai	21.277997	-157.821242	10.08047619
12	83.22751908	Abundant for aquatic life	2016-03-27	F-Alawai	21.277616	-157.81996	9.084285714
13	82.56742017	Abundant for aquatic life	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	8.7065
14	81.97279036	Abundant for aquatic life	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	8.34675
15	81.69589586	Abundant for aquatic life	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	8.1725
16	81.52405407	Abundant for aquatic life	2016-06-02	LIELUPE	56.973479	23.861068	8.062105263
17	81.25925663	Abundant for aquatic life	2016-03-27	D-Alawai	21.274992	-157.817526	7.8885
18	81.21940869	Abundant for aquatic life	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	7.862
19	81.17148906	Abundant for aquatic life	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	7.83
20	81.13271344	Abundant for aquatic life	2016-06-19	B-Kokemaenjoki	61.493654	21.827547	7.804
21	81.05410906	Abundant for aquatic life	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	7.751
22	80.89645805	Abundant for aquatic life	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	7.6435
23	80.82682495	Abundant for aquatic life	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	7.5955
24	80.58742794	Abundant for aquatic life	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	7.428
25	80.58672156	Abundant for aquatic life	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	7.4275
26	80.53254245	Abundant for aquatic life	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	7.389047619
27	80.51843239	Abundant for aquatic life	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	7.379
28	80.48061169	Abundant for aquatic life	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	7.352
29	80.41788607	Abundant for aquatic life	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	7.307
29	80.41788607	Abundant for aquatic life	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	7.307
31	80.24838013	Abundant for aquatic life	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	7.184
32	80.07158867	Abundant for aquatic life	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	7.0535
33	80.02027228	Abundant for aquatic life	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	7.724
34	62.99880526	Supports growth and activity for aquatic life	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	6.912727273
35	62.87778447	Supports growth and activity for aquatic life	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	6.880526316
36	62.58246633	Supports growth and activity for aquatic life	2016-06-02	B-Daugava MS	56.914538	24.167233	6.8005
37	62.23987292	Supports growth and activity for aquatic life	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	6.705
38	62.22382567	Supports growth and activity for aquatic life	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	6.700454545
39	62.04898023	Supports growth and activity for aquatic life	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	6.6505
40	62.03163113	Supports growth and activity for aquatic life	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	6.6455
41	61.83406114	Supports growth and activity for aquatic life	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	6.588
42	61.69365461	Supports growth and activity for aquatic life	2016-06-19	D-Kokemaenjoki	61.491615	21.801848	6.5465
43	61.69197397	Supports growth and activity for aquatic life	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	6.546
44	61.67853825	Supports growth and activity for aquatic life	2016-09-25	E-Nam Lik US	18.590006	102.491119	6.542
45	61.49608944	Supports growth and activity for aquatic life	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	6.4871875
46	61.31361461	Supports growth and activity for aquatic life	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	6.431428571
47	61.25398512	Supports growth and activity for aquatic life	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	6.413
48	61.18003026	Supports growth and activity for aquatic life	2016-09-24	A-Mekong	17.907442	102.616652	6.39
49	61.07945332	Supports growth and activity for aquatic life	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	6.358461538
50	61.04929967	Supports growth and activity for aquatic life	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	6.348947368
51	61.04509664	Supports growth and activity for aquatic life	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	6.347619048
52	61.03997595	Supports growth and activity for aquatic life	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	6.346
53	60.86956522	Supports growth and activity for aquatic life	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	6.25
54	60.69628206	Supports growth and activity for aquatic life	2016-06-02	A-Daugava US	56.91348	24.169145	6.2355
55	60.46626144	Supports growth and activity for aquatic life	2016-09-25	F-Nam Lik DS	18.539164	102.51056	6.159473684
56	60.16184337	Supports growth and activity for aquatic life	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	6.056190476
57	43.66280503	Supports spawning for aquatic life	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	5.92875
58	43.33949237	Supports spawning for aquatic life	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	5.8585
59	42.86585366	Supports spawning for aquatic life	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	5.752
60	42.82670725	Supports spawning for aquatic life	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	5.743
61	42.77904328	Supports spawning for aquatic life	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	5.732
62	42.70791939	Supports spawning for aquatic life	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	5.7155
63	42.09169808	Supports spawning for aquatic life	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	5.568095238
64	41.84939524	Supports spawning for aquatic life	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	5.507857143
65	41.52161601	Supports spawning for aquatic life	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	5.424210526
66	41.45539067	Supports spawning for aquatic life	2016-06-02	C-Daugava DS	56.937357	24.114167	5.407
67	41.33333333	Supports spawning for aquatic life	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	5.375
68	41.06556658	Supports spawning for aquatic life	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	5.3035
69	40.99370189	Supports spawning for aquatic life	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	5.284
70	40.63908754	Supports spawning for aquatic life	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	5.185789474
71	40.47146402	Supports spawning for aquatic life	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	5.138181818
72	40.14361653	Supports spawning for aquatic life	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	5.042777778
73	33.1439394	Hazard for aquatic life	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	4.982857143
74	32.91097581	Hazard for aquatic life	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	4.9615
75	32.50975293	Hazard for aquatic life	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	4.924
76	31.4324203	Hazard for aquatic life	2016-09-24	B-Nam Ngam US	18.150329	102.635581	4.818571429
77	31.39269407	Hazard for aquatic life	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	4.814545455
78	30.53435115	Hazard for aquatic life	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	4.725
79	29.6735905	Hazard for aquatic life	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	4.63
80	28.54288569	Hazard for aquatic life	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	4.4965

(stdin):

Fig. 6.49 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of aquatic life (Query: aquatic life, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, and All aquatic life extinction)).

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semanticordering	factor	keyword	ndate	location	latitude	longitude	ph	totaldissolvedsolid	turbidity
1	66.64209524	Hazard and chronic toxic for drinking	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	7.356	66	8.399
2	65.4815873	Hazard and chronic toxic for drinking	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	6.048571429	60.04761905	2.087142857
3	64.89035088	Hazard and chronic toxic for drinking	2016-06-02	LIELUPE	56.973479	23.861068	8.06	536.1578947	1.464736842
4	64.14965986	Hazard and chronic toxic for drinking	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818	8.247142857	1624.285714	28.205
5	63.822	Hazard and chronic toxic for drinking	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	6.851	61.5	8.2395
6	63.15	Hazard and chronic toxic for drinking	2016-06-02	A-Daugava US	56.91348	24.169145	7.3515	178.15	0
7	63.001	Hazard and chronic toxic for drinking	2016-06-02	C-Daugava DS	56.937357	24.114167	7.2245	175.4	5.646
8	62.26277778	Hazard and chronic toxic for drinking	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	6.402	65	9.1945
9	60.42361905	Hazard and chronic toxic for drinking	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	7.2065	68	9.581
10	60.13152381	Hazard and chronic toxic for drinking	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	7.1885	61.3	9.667
11	58.43994709	Hazard and chronic toxic for drinking	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	5.974761905	59.95238095	8.985238095
12	57.45104762	Hazard and chronic toxic for drinking	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	6.7905	67	9.342
13	57.32588745	Hazard and chronic toxic for drinking	2016-09-25	D-Nam Ngam DS	18.52493	102.513324	6.621818182	88.09090909	8.795909091
14	56.73122222	Hazard and chronic toxic for drinking	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	6.3835	53.05	3.9075
15	56.51944444	Hazard and chronic toxic for drinking	2016-06-02	B-Daugava MS	56.914538	24.167233	7.5955	173.1	0.005
16	56.38633333	Hazard and chronic toxic for drinking	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	6.2045	61.05	4.0325
17	56.25888889	Hazard and chronic toxic for drinking	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	6.1735	70.7	9.4175
18	55.48862434	Hazard and chronic toxic for drinking	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	6.918571429	237.0952381	9.013333333
19	54.22323232	Hazard and chronic toxic for drinking	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	6.057272727	62.36363636	5.015909091
20	54.04333333	Hazard and chronic toxic for drinking	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	6.4225	72.1	9.9045
21	53.78769841	Hazard and chronic toxic for drinking	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	6.6465	59.1	0.4315
22	53.42152778	Hazard and chronic toxic for drinking	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	5.981	53.05	0.9975
23	48.36547619	Hazard and chronic toxic for drinking	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	6.601	66.4	1.2045
24	47.27543859	Hazard and chronic toxic for drinking	2016-03-27	0-Alawai	21.284561	-157.839613	8.331052632	27831.57895	0.324210526
25	44.44166667	Hazard and chronic toxic for drinking	2016-03-27	M-Alawai	21.287627	-157.83978	8.4365	27410	0.858
26	43.92926587	Hazard and chronic toxic for drinking	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	6.2655	56.975	12.628
27	43.44223985	Hazard and chronic toxic for drinking	2016-03-27	E-Alawai	21.277997	-157.821242	8.378571429	27800	2.543809524
28	43.31746031	Hazard and chronic toxic for drinking	2016-03-27	L-Alawai	21.288718	-157.834047	8.426666667	21276.19048	1.224761905
29	43.22472222	Hazard and chronic toxic for drinking	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	6.4135	65.15	3.214
30	42.72883598	Hazard and chronic toxic for drinking	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	6.381666667	67	10.76555556
31	42.4968254	Hazard and chronic toxic for drinking	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	6.4025	69.4	10.665
32	41.79285714	Hazard and chronic toxic for drinking	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	6.487	70.6	11.6
33	39.69620811	Hazard and chronic toxic for drinking	2016-03-27	G-Alawai	21.280087	-157.823755	8.388095238	28066.66667	3.533809524
34	39.54444444	Hazard and chronic toxic for drinking	2016-03-25	C-Manoa ST	21.311147	-157.808813	6.524	11.26666667	16.04133333
35	39.35493828	Hazard and chronic toxic for drinking	2016-03-27	K-Alawai	21.287292	-157.8321	8.301428571	18457.14286	3.820952381
36	38.58707483	Hazard and chronic toxic for drinking	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	7.482142857	63.14285714	5.736904762
37	37.69333333	Hazard and chronic toxic for drinking	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	6.5325	65.95	27.665
38	37.64126984	Hazard and chronic toxic for drinking	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	6.573333333	63.42857143	11.49333333
39	37.50729167	Hazard and chronic toxic for drinking	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	6.6153125	63.25	49.9790625
40	37.24285714	Hazard and chronic toxic for drinking	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	6.645714286	68.14285714	11.98095238
41	37.02333333	Hazard and chronic toxic for drinking	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	6.723	67	10.771
42	36.82333333	Hazard and chronic toxic for drinking	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	6.8415	61.15	458
43	36.41428571	Hazard and chronic toxic for drinking	2016-09-24	B-Nam Ngam US	18.150329	102.635581	6.785714286	79	34.27142857
44	36.39297052	Hazard and chronic toxic for drinking	2016-03-27	N-Alawai	21.28756	-157.843219	8.5635	27845	2.128
45	36.315	Hazard and chronic toxic for drinking	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	6.888	71.75	55.4245
46	36.07894737	Hazard and chronic toxic for drinking	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	6.77	90.63157895	19.19473684
47	35.82142857	Hazard and chronic toxic for drinking	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	7.143571429	61	14.75
48	35.70833333	Hazard and chronic toxic for drinking	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	7.1575	63	286.65
49	35.67052632	Hazard and chronic toxic for drinking	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	6.274210526	37.21052632	2.830526316
50	35.56	Hazard and chronic toxic for drinking	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	7.2015	63.05	17.44
51	35.36771429	Hazard and chronic toxic for drinking	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	6.8535	62.3	5.052
52	35.04666667	Hazard and chronic toxic for drinking	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	7.277	70.9	13.315
53	34.82857143	Hazard and chronic toxic for drinking	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	6.648	65	4.675
54	34.575	Hazard and chronic toxic for drinking	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	7.4475	68	10.0395
55	34.54785714	Hazard and chronic toxic for drinking	2016-03-26	H-Alawai	21.283046	-157.827202	8.5095	28535	7.8845
56	34.40757576	Hazard and chronic toxic for drinking	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	7.552727273	62.5	12
57	34.22105263	Hazard and chronic toxic for drinking	2016-09-25	F-Nam Lik DS	18.539164	102.51056	7.273684211	96	35.66315789
58	34.21033333	Hazard and chronic toxic for drinking	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	7.4245	81	14.54
59	33.7165368	Hazard and chronic toxic for drinking	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	7.155	63	6.176818182
60	33.56666667	Hazard and chronic toxic for drinking	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526	7.578333333	85.16666667	14.54444444
61	33.03847619	Unfit and toxic for drinking	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	6.889	62.7	5.7155
62	32.57833333	Unfit and toxic for drinking	2016-09-25	E-Nam Lik US	18.590006	102.491119	7.7465	98	87.76
63	32.25438596	Unfit and toxic for drinking	2016-09-24	A-Mekong	17.907442	102.616652	7.44	138.3684211	399.2105263
64	31.56462585	Unfit and toxic for drinking	2016-03-27	F-Alawai	21.277616	-157.81996	8.080952381	18061.90476	66.72857143
65	31.075	Unfit and toxic for drinking	2016-03-27	D-Alawai	21.274992	-157.817526	8.1495	28355	52.3845
66	30.44642857	Unfit and toxic for drinking	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	8.2375	25633.33333	35.69166667
67	30.05561905	Unfit and toxic for drinking	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	7.889	64.4	8.828
68	29.1525974	Unfit and toxic for drinking	2016-03-27	I-Alawai	21.283438	-157.82764	8.418636364	27922.72727	20.22863636
69	29.05102041	Unfit and toxic for drinking	2016-03-27	J-Alawai	21.28593	-157.83054	8.432857143	26323.80952	19.81904762
70	28.21690476	Unfit and toxic for drinking	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	6.844	61.05	6.0275
71	28.07161905	Unfit and toxic for drinking	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	6.9405	62.8	7.079
72	26.53123016	Unfit and toxic for drinking	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	7.001666667	63.875	7.79125
73	26.41567099	Unfit and toxic for drinking	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	7.513181818	68	8.813181818
74	25.51424909	Unfit and toxic for drinking	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	7.216538462	64.80769231	8.358846154
75	24.21795238	Unfit and toxic for drinking	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	7.546	62.75	9.4845
76	22.7075188	Unfit and toxic for drinking	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	7.507894737	63.42105263	9.765789474
77	21.46805556	Unfit and toxic for drinking	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	6.1475	55.35	17.747
78	21.42083333	Unfit and toxic for drinking	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	6.058	57.35	33.9985
79	21.34111111	Unfit and toxic for drinking	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	6.184	57	18.605
80	21.30305556	Unfit and toxic for drinking	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	6.1555	60.65	27.685

Fig. 6.50 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of drinking (Query: drinking, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Optimum for drinking, Hazard and chronic toxic for drinking, and Unfit and toxic for drinking)).

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semanticordering	factor	keyword	ndate	location	latitude	longitude	ph
1	99.71764706	Absent in all fish frogs and insects	2016-03-25	C-Manoa ST	21.311147	-157.808813	6.524
2	99.61764706	Absent in all fish frogs and insects	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	6.5325
3	99.13725491	Absent in all fish frogs and insects	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	6.573333333
4	98.81176471	Absent in all fish frogs and insects	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	6.601
5	98.64338235	Absent in all fish frogs and insects	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	6.6153125
6	98.56684492	Absent in all fish frogs and insects	2016-09-25	D-Nam Ngam DS	18.52493	102.513324	6.621818182
7	98.28571428	Absent in all fish frogs and insects	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	6.645714286
8	98.27647059	Absent in all fish frogs and insects	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	6.6465
9	97.37647059	Absent in all fish frogs and insects	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	6.723
10	96.82352941	Absent in all fish frogs and insects	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	6.77
11	96.63865546	Absent in all fish frogs and insects	2016-09-24	B-Nam Ngam US	18.150329	102.635581	6.785714286
12	96.58235294	Absent in all fish frogs and insects	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	6.7905
13	95.98235294	Absent in all fish frogs and insects	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	6.8415
14	95.95294118	Absent in all fish frogs and insects	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	6.844
15	95.87058824	Absent in all fish frogs and insects	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	6.851
16	95.84117647	Absent in all fish frogs and insects	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	6.8535
17	95.43529412	Absent in all fish frogs and insects	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	6.888
18	95.42352941	Absent in all fish frogs and insects	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	6.889
19	95.07563025	Absent in all fish frogs and insects	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	6.918571429
20	94.81764706	Absent in all fish frogs and insects	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	6.9405
21	93.15686274	Absent in all fish frogs and insects	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	7.081666667
22	92.42857142	Absent in all fish frogs and insects	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	7.143571429
23	92.29411765	Absent in all fish frogs and insects	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	7.155
24	92.26470588	Absent in all fish frogs and insects	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	7.1575
25	91.9	Absent in all fish frogs and insects	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	7.1885
26	91.74705882	Absent in all fish frogs and insects	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	7.2015
27	91.68823529	Absent in all fish frogs and insects	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	7.2065
28	91.57013574	Absent in all fish frogs and insects	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	7.216538462
29	91.47647059	Absent in all fish frogs and insects	2016-06-02	C-Daugava DS	56.937357	24.114167	7.2245
30	90.89783281	Absent in all fish frogs and insects	2016-09-25	F-Nam Lik DS	18.539164	102.51056	7.273684211
31	90.85882353	Absent in all fish frogs and insects	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	7.277
32	89.98235294	Absent in all fish frogs and insects	2016-06-02	A-Daugava US	56.91348	24.169145	7.3515
33	89.92941176	Absent in all fish frogs and insects	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	7.356
34	89.12352941	Absent in all fish frogs and insects	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	7.4245
35	88.94117647	Absent in all fish frogs and insects	2016-09-24	A-Mekong	17.907442	102.616652	7.44
36	88.85294118	Absent in all fish frogs and insects	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	7.4475
37	88.44537815	Absent in all fish frogs and insects	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	7.482142857
38	88.14241486	Absent in all fish frogs and insects	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	7.507894737
39	88.08021391	Absent in all fish frogs and insects	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	7.513181818
40	87.69411765	Absent in all fish frogs and insects	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	7.546
41	87.61497326	Absent in all fish frogs and insects	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	7.552727273
42	87.31372549	Absent in all fish frogs and insects	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526	7.578333333
43	87.11176471	Absent in all fish frogs and insects	2016-06-02	B-Daugava MS	56.914538	24.167233	7.5955
44	86.7	Absent in all fish frogs and insects	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	6.3325
45	85.33529412	Absent in all fish frogs and insects	2016-09-25	E-Nam Lik US	18.590006	102.491119	7.7465
46	83.65882353	Absent in all fish frogs and insects	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	7.889
47	81.64705882	Absent in all fish frogs and insects	2016-06-02	LIELUPE	56.973479	23.861068	8.06
48	81.40056022	Absent in all fish frogs and insects	2016-03-27	F-Alawai	21.277616	-157.81996	8.080952381
49	80.59411765	Absent in all fish frogs and insects	2016-03-27	D-Alawai	21.274992	-157.817526	8.1495
50	78.05714284	Optimum for fish and shrimp	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	6.048571429
51	77.70909092	Optimum for fish and shrimp	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	6.057272727
52	77.68	Optimum for fish and shrimp	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	6.058
53	74.1	Optimum for fish and shrimp	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	6.1475
54	73.78	Optimum for fish and shrimp	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	6.1555
55	73.06	Optimum for fish and shrimp	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	6.1735
56	72.64	Optimum for fish and shrimp	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	6.184
57	71.82	Optimum for fish and shrimp	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	6.2045
58	70.11428572	Optimum for fish and shrimp	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	6.247142857
59	69.38	Optimum for fish and shrimp	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	6.2655
60	69.03157896	Optimum for fish and shrimp	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	6.274210526
61	67.24210528	Optimum for fish and shrimp	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	6.318947368
62	65.26	Optimum for fish and shrimp	2016-06-19	D-Kokemaenjoki	61.491615	21.801848	6.3685
63	64.73333332	Optimum for fish and shrimp	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	6.381666667
64	64.66	Optimum for fish and shrimp	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	6.3835
65	63.92	Optimum for fish and shrimp	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	6.402
66	63.9	Optimum for fish and shrimp	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	6.4025
67	63.46	Optimum for fish and shrimp	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	6.4135
68	63.1	Optimum for fish and shrimp	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	6.4225
69	60.52	Optimum for fish and shrimp	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	6.487
70	54.08	Bacteria begin die and plankton begin disappear	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	6.648
71	40.5047619	Bacteria begin die and plankton begin disappear	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	5.974761905
72	40.38	Bacteria begin die and plankton begin disappear	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	5.981
73	38.8604119	Hazard for fish and salmon dying	2016-03-27	0-Alawai	21.284561	-157.839613	8.331052632
74	38.44720497	Hazard for fish and salmon dying	2016-03-27	E-Alawai	21.277997	-157.821242	8.378571429
75	38.36438923	Hazard for fish and salmon dying	2016-03-27	G-Alawai	21.280087	-157.823755	8.388095238
76	38.09881423	Hazard for fish and salmon dying	2016-03-27	I-Alawai	21.283438	-157.82764	8.418636364
77	38.0289855	Hazard for fish and salmon dying	2016-03-27	L-Alawai	21.288718	-157.834047	8.426666667
78	37.97515528	Hazard for fish and salmon dying	2016-03-27	J-Alawai	21.28593	-157.83054	8.432857143
79	37.94347826	Hazard for fish and salmon dying	2016-03-27	M-Alawai	21.287627	-157.83978	8.4365
80	37.30869565	Hazard for fish and salmon dying	2016-03-26	H-Alawai	21.283046	-157.827202	8.5095

(stdin):

Fig. 6.51 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of fish (Query: fish, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant for fish, Optimum for fish and shrimp, Bacteria and plankton being disappear, Hazard for fish and salmon dying, and All fish extinction)).

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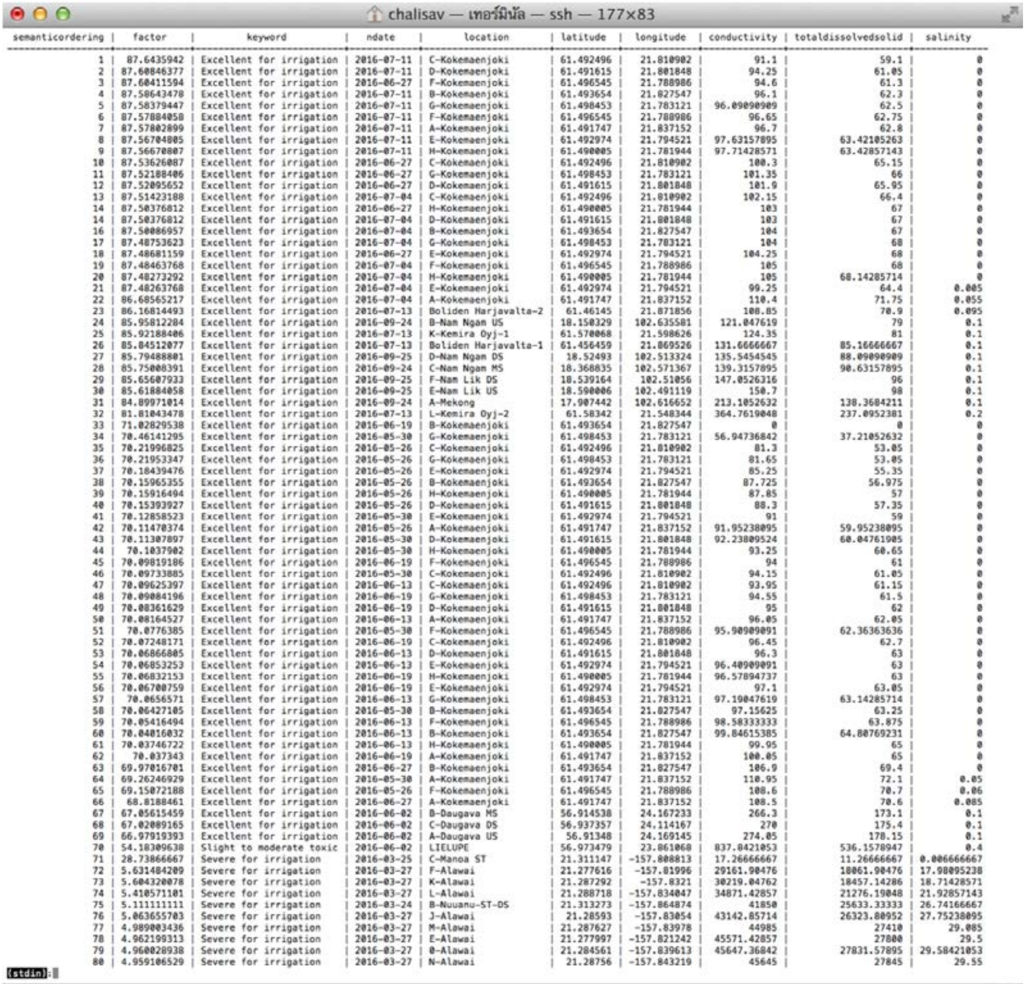
semanticordering	factor	keyword	ndate	location	latitude	longitude	ph	conductivity	totaldissolvedsolid
1	95.39277778	Optimun for industrial processes	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	6.5325	101.9	65.95
2	95.38835979	Optimun for industrial processes	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	6.573333333	97.71428571	63.42857143
3	95.35444444	Optimun for industrial processes	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	6.6465	91.1	59.1
4	95.22013889	Optimun for industrial processes	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	6.6153125	97.15625	63.25
5	95.06777778	Optimun for industrial processes	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	6.601	102.15	66.4
6	94.74761905	Optimun for industrial processes	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	6.645714286	105	68.14285714
7	94.48666667	Optimun for industrial processes	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	6.723	103	67
8	94.35611111	Optimun for industrial processes	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	6.8415	93.95	61.15
9	94.34166667	Optimun for industrial processes	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	6.844	94.25	61.05
10	94.28888889	Optimun for industrial processes	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	6.851	94.55	61.5
11	94.21666667	Optimun for industrial processes	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	6.8535	96.1	62.3
12	94.16444444	Optimun for industrial processes	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	6.7905	104	67
13	94.03777778	Optimun for industrial processes	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	6.889	96.45	62.7
14	93.8	Optimun for industrial processes	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	6.9405	96.7	62.8
15	93.51010101	Optimun for industrial processes	2016-09-25	D-Nam Ngam DS	18.52493	102.513324	6.621818182	135.5454545	88.09090909
16	93.43055556	Optimun for industrial processes	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	6.888	110.4	71.75
17	93.40687831	Optimun for industrial processes	2016-09-24	B-Nam Ngam US	18.150329	102.635581	6.785714286	121.047619	79
18	93.32333333	Optimun for industrial processes	2016-06-02	C-Daugava DS	56.937357	24.114167	7.2245	270	175.4
19	93.09490741	Optimun for industrial processes	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	7.081666667	98.58333333	63.875
20	93.01746032	Optimun for industrial processes	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	7.143571429	94	61
21	92.84646465	Optimun for industrial processes	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	7.155	96.40909091	63
22	92.83777778	Optimun for industrial processes	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	7.1575	96.3	63
23	92.79444444	Optimun for industrial processes	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	7.1885	94.6	61.3
24	92.68304094	Optimun for industrial processes	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	6.77	139.3157895	90.63157895
25	92.62277778	Optimun for industrial processes	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	7.2015	97.1	63.05
26	92.43632478	Optimun for industrial processes	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	7.216538462	99.84615385	64.80769231
27	92.27666667	Optimun for industrial processes	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	7.2065	104.25	68
28	91.76444444	Optimun for industrial processes	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	7.277	108.85	70.9
29	91.74333333	Optimun for industrial processes	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	7.356	101.35	66
30	91.37037037	Optimun for industrial processes	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	7.482142857	97.19047619	63.14285714
31	91.2368421	Optimun for industrial processes	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	7.507894737	97.63157895	63.42105263
32	91.18888889	Optimun for industrial processes	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	7.4475	105	68
33	91.11166667	Optimun for industrial processes	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	7.546	96.65	62.75
34	91.10252525	Optimun for industrial processes	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	7.552727273	96.09090909	62.5
35	90.91919192	Optimun for industrial processes	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	7.513181818	104	68
36	90.42777778	Optimun for industrial processes	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	7.4245	124.35	81
37	90.09356725	Optimun for industrial processes	2016-09-25	F-Nam Lik DS	18.539164	102.51056	7.273684211	147.0526316	96
38	89.47444444	Optimun for industrial processes	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	7.889	99.25	64.4
39	89.44259259	Optimun for industrial processes	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526	7.578333333	131.6666667	85.16666667
40	87.84444444	Optimun for industrial processes	2016-09-25	E-Nam Lik US	18.590006	102.491119	7.7465	150.7	98
41	86.30394737	Optimun for industrial processes	2016-09-24	A-Mekong	17.907442	102.616652	7.44	213.1052632	138.3684211
42	85.99007936	Optimun for industrial processes	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	6.048571429	92.23809524	60.04761905
43	85.93458333	Optimun for industrial processes	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	6.058	88.3	57.35
44	85.6969697	Optimun for industrial processes	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	6.057272727	95.90909091	62.36363636
45	84.24541667	Optimun for industrial processes	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	6.1475	85.25	55.35
46	84.18722222	Optimun for industrial processes	2016-06-02	A-Daugava US	56.91348	24.169145	7.3515	274.05	178.15
47	83.81958333	Optimun for industrial processes	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	6.1555	93.25	60.65
48	83.44333333	Optimun for industrial processes	2016-06-02	B-Daugava MS	56.914538	24.167233	7.5955	266.3	173.1
49	83.43083333	Optimun for industrial processes	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	6.184	87.85	57
50	82.9525	Optimun for industrial processes	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	6.1735	108.6	70.7
51	82.81458333	Optimun for industrial processes	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	6.2045	94.15	61.05
52	82.63640352	Optimun for industrial processes	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	6.274210526	56.94736842	37.21052632
53	82.06547619	Optimun for industrial processes	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	6.247142857	91	59
54	81.80354167	Optimun for industrial processes	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	6.2655	87.725	56.975
55	80.43640352	Optimun for industrial processes	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	6.318947368	96.57894737	63
56	80.19791667	Optimun for industrial processes	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	6.3325	96.05	62.05
57	78.97499999	Slightly corrosive scaling and fouling	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	6.381666667	103	67
58	78.66916667	Slightly corrosive scaling and fouling	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	6.402	99.95	65
59	78.43333333	Slightly corrosive scaling and fouling	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	6.4025	106.9	69.4
60	78.42958333	Slightly corrosive scaling and fouling	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	6.4135	100.3	65.15
61	78.31492063	Slightly corrosive scaling and fouling	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	6.918571429	364.7619048	237.0952381
62	77.89833333	Slightly corrosive scaling and fouling	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	6.4225	110.95	72.1
63	76.68666667	Slightly corrosive scaling and fouling	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	6.487	108.5	70.6
64	73.7475	Slightly corrosive scaling and fouling	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	6.648	100.05	65
65	66.18444444	Slightly corrosive scaling and fouling	2016-03-25	C-Manoa ST	21.311147	-157.808813	6.524	17.26666667	11.26666667
66	62.083	Slightly corrosive scaling and fouling	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	5.981	81.3	53.05
67	61.87777778	Slightly corrosive scaling and fouling	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	5.974761905	91.95238095	59.95238095
68	53.41666667	Moderate corrosive scaling and fouling	2016-06-19	B-Kokemaenjoki	61.493654	21.827547	10.9875	0	0
69	33.6245614	Hightly corrosive scaling and fouling	2016-06-02	LIELUPE	56.973479	23.861068	8.06	837.8421053	536.1578947
70	20.37556253	Hightly corrosive scaling and fouling	2016-03-24	A-Nuuanu-ST-US	21.314362	-157.861818	8.247142857	25214.28571	1624.285714
71	13.47252747	Unfit for industrial processes	2016-03-27	F-Alawai	21.277616	-157.81996	8.080952381	29161.90476	18061.90476
72	13.15615385	Unfit for industrial processes	2016-03-27	D-Alawai	21.274992	-157.817526	8.1495	46400	28355
73	12.75	Unfit for industrial processes	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	8.2375	41850	25633.33333
74	12.45494506	Unfit for industrial processes	2016-03-27	K-Alawai	21.287292	-157.8321	8.301428571	30219.04762	18457.14286
75	12.31821862	Unfit for industrial processes	2016-03-27	0-Alawai	21.284561	-157.839613	8.331052632	45647.36842	27831.57895
76	12.0989011	Unfit for industrial processes	2016-03-27	E-Alawai	21.277997	-157.821242	8.378571429	45571.42857	27800
77	12.05494506	Unfit for industrial processes	2016-03-27	G-Alawai	21.280087	-157.823755	8.388095238	46000	28066.66667
78	11.91398601	Unfit for industrial processes	2016-03-27	I-Alawai	21.283438	-157.82764	8.418636364	45772.72727	27922.72727
79	11.87692308	Unfit for industrial processes	2016-03-27	L-Alawai	21.288718	-157.834047	8.426666667	34871.42857	21276.19048
80	11.84835165	Unfit for industrial processes	2016-03-27	J-Alawai	21.28593	-157.83054	8.432857143	43142.85714	26323.80952

(stdin):

Fig. 6.52 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of industry (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).



semanticordering	factor	keyword	ndate	location	latitude	longitude	conductivity	totaldissolvedsolid	salinity
1	87.6435942	Excellent for irrigation	2016-07-11	C-Kokemaenjoki	61.492496	21.810902	91.1	59.1	0
2	87.60846377	Excellent for irrigation	2016-07-11	D-Kokemaenjoki	61.491615	21.801848	94.25	61.05	0
3	87.60411594	Excellent for irrigation	2016-06-27	F-Kokemaenjoki	61.496545	21.788986	94.6	61.3	0
4	87.58643478	Excellent for irrigation	2016-07-11	B-Kokemaenjoki	61.493654	21.827547	96.1	62.3	0
5	87.58379447	Excellent for irrigation	2016-07-11	G-Kokemaenjoki	61.498453	21.783121	96.09090909	62.5	0
6	87.57884058	Excellent for irrigation	2016-07-11	F-Kokemaenjoki	61.496545	21.788986	96.65	62.75	0
7	87.57802899	Excellent for irrigation	2016-07-11	A-Kokemaenjoki	61.491747	21.837152	96.7	62.8	0
8	87.56704805	Excellent for irrigation	2016-07-11	E-Kokemaenjoki	61.492974	21.794521	97.63157895	63.42105263	0
9	87.56670807	Excellent for irrigation	2016-07-11	H-Kokemaenjoki	61.490005	21.781944	97.71428571	63.42857143	0
10	87.53626087	Excellent for irrigation	2016-06-27	C-Kokemaenjoki	61.492496	21.810902	100.3	65.15	0
11	87.52188406	Excellent for irrigation	2016-06-27	G-Kokemaenjoki	61.498453	21.783121	101.35	66	0
12	87.52095652	Excellent for irrigation	2016-06-27	D-Kokemaenjoki	61.491615	21.801848	101.9	65.95	0
13	87.51423188	Excellent for irrigation	2016-07-04	C-Kokemaenjoki	61.492496	21.810902	102.15	66.4	0
14	87.50376812	Excellent for irrigation	2016-06-27	H-Kokemaenjoki	61.490005	21.781944	103	67	0
14	87.50376812	Excellent for irrigation	2016-07-04	D-Kokemaenjoki	61.491615	21.801848	103	67	0
16	87.50086957	Excellent for irrigation	2016-07-04	B-Kokemaenjoki	61.493654	21.827547	104	67	0
17	87.48753623	Excellent for irrigation	2016-07-04	G-Kokemaenjoki	61.498453	21.783121	104	68	0
18	87.48681159	Excellent for irrigation	2016-06-27	E-Kokemaenjoki	61.492974	21.794521	104.25	68	0
19	87.48463768	Excellent for irrigation	2016-07-04	F-Kokemaenjoki	61.496545	21.788986	105	68	0
20	87.48273292	Excellent for irrigation	2016-07-04	H-Kokemaenjoki	61.490005	21.781944	105	68.14285714	0
21	87.48263768	Excellent for irrigation	2016-07-04	E-Kokemaenjoki	61.492974	21.794521	99.25	64.4	0.005
22	86.68565217	Excellent for irrigation	2016-07-04	A-Kokemaenjoki	61.491747	21.837152	110.4	71.75	0.055
23	86.16814493	Excellent for irrigation	2016-07-13	Boliden Harjavalta-2	61.46145	21.871856	108.85	70.9	0.095
24	85.95812284	Excellent for irrigation	2016-09-24	B-Nam Ngam US	18.150329	102.635581	121.047619	79	0.1
25	85.92188406	Excellent for irrigation	2016-07-13	K-Kemira Oyj-1	61.570068	21.598626	124.35	81	0.1
26	85.84512077	Excellent for irrigation	2016-07-13	Boliden Harjavalta-1	61.456459	21.869526	131.6666667	85.16666667	0.1
27	85.79488801	Excellent for irrigation	2016-09-25	D-Nam Ngam DS	18.52493	102.513324	135.5454545	88.09090909	0.1
28	85.75008391	Excellent for irrigation	2016-09-24	C-Nam Ngam MS	18.368835	102.571367	139.3157895	90.63157895	0.1
29	85.65607933	Excellent for irrigation	2016-09-25	F-Nam Lik DS	18.539164	102.51056	147.0526316	96	0.1
30	85.61884058	Excellent for irrigation	2016-09-25	E-Nam Lik US	18.590006	102.491119	150.7	98	0.1
31	84.89971014	Excellent for irrigation	2016-09-24	A-Mekong	17.907442	102.616652	213.1052632	138.3684211	0.1
32	81.81043478	Excellent for irrigation	2016-07-13	L-Kemira Oyj-2	61.58342	21.548344	364.7619048	237.0952381	0.2
33	71.02829538	Excellent for irrigation	2016-06-19	B-Kokemaenjoki	61.493654	21.827547	0	0	0
34	70.46141295	Excellent for irrigation	2016-05-30	G-Kokemaenjoki	61.498453	21.783121	56.94736842	37.21052632	0
35	70.21996825	Excellent for irrigation	2016-05-26	C-Kokemaenjoki	61.492496	21.810902	81.3	53.05	0
36	70.21953347	Excellent for irrigation	2016-05-26	G-Kokemaenjoki	61.498453	21.783121	81.65	53.05	0
37	70.18439476	Excellent for irrigation	2016-05-26	E-Kokemaenjoki	61.492974	21.794521	85.25	55.35	0
38	70.15965355	Excellent for irrigation	2016-05-26	B-Kokemaenjoki	61.493654	21.827547	87.725	56.975	0
39	70.15916494	Excellent for irrigation	2016-05-26	H-Kokemaenjoki	61.490005	21.781944	87.85	57	0
40	70.15393927	Excellent for irrigation	2016-05-26	D-Kokemaenjoki	61.491615	21.801848	88.3	57.35	0
41	70.12858523	Excellent for irrigation	2016-05-30	E-Kokemaenjoki	61.492974	21.794521	91	59	0
42	70.11470374	Excellent for irrigation	2016-05-26	A-Kokemaenjoki	61.491747	21.837152	91.95238095	59.95238095	0
43	70.11307897	Excellent for irrigation	2016-05-30	D-Kokemaenjoki	61.491615	21.801848	92.23809524	60.04761905	0
44	70.1037902	Excellent for irrigation	2016-05-30	H-Kokemaenjoki	61.490005	21.781944	93.25	60.65	0
45	70.09819186	Excellent for irrigation	2016-06-19	F-Kokemaenjoki	61.496545	21.788986	94	61	0
46	70.09733885	Excellent for irrigation	2016-05-30	C-Kokemaenjoki	61.492496	21.810902	94.15	61.05	0
47	70.09625397	Excellent for irrigation	2016-06-13	C-Kokemaenjoki	61.492496	21.810902	93.95	61.15	0
48	70.09084196	Excellent for irrigation	2016-06-19	G-Kokemaenjoki	61.498453	21.783121	94.55	61.5	0
49	70.08361629	Excellent for irrigation	2016-06-19	D-Kokemaenjoki	61.491615	21.801848	95	62	0
50	70.08164527	Excellent for irrigation	2016-06-13	A-Kokemaenjoki	61.491747	21.837152	96.05	62.05	0
51	70.0776385	Excellent for irrigation	2016-05-30	F-Kokemaenjoki	61.496545	21.788986	95.90909091	62.36363636	0
52	70.07248171	Excellent for irrigation	2016-06-19	C-Kokemaenjoki	61.492496	21.810902	96.45	62.7	0
53	70.06866805	Excellent for irrigation	2016-06-13	D-Kokemaenjoki	61.491615	21.801848	96.3	63	0
54	70.06853253	Excellent for irrigation	2016-06-13	E-Kokemaenjoki	61.492974	21.794521	96.40909091	63	0
55	70.06832153	Excellent for irrigation	2016-06-19	H-Kokemaenjoki	61.490005	21.781944	96.57894737	63	0
56	70.06700759	Excellent for irrigation	2016-06-19	E-Kokemaenjoki	61.492974	21.794521	97.1	63.05	0
57	70.0656571	Excellent for irrigation	2016-06-13	G-Kokemaenjoki	61.498453	21.783121	97.19047619	63.14285714	0
58	70.06427105	Excellent for irrigation	2016-05-30	B-Kokemaenjoki	61.493654	21.827547	97.15625	63.25	0
59	70.05416494	Excellent for irrigation	2016-06-13	F-Kokemaenjoki	61.496545	21.788986	98.58333333	63.875	0
60	70.04016032	Excellent for irrigation	2016-06-13	B-Kokemaenjoki	61.493654	21.827547	99.84615385	64.80769231	0
61	70.03746722	Excellent for irrigation	2016-06-13	H-Kokemaenjoki	61.490005	21.781944	99.95	65	0
62	70.037343	Excellent for irrigation	2016-06-19	A-Kokemaenjoki	61.491747	21.837152	100.05	65	0
63	69.97016701	Excellent for irrigation	2016-06-27	B-Kokemaenjoki	61.493654	21.827547	106.9	69.4	0
64	69.26246929	Excellent for irrigation	2016-05-30	A-Kokemaenjoki	61.491747	21.837152	110.95	72.1	0.05
65	69.15072188	Excellent for irrigation	2016-05-26	F-Kokemaenjoki	61.496545	21.788986	108.6	70.7	0.06
66	68.8188461	Excellent for irrigation	2016-06-27	A-Kokemaenjoki	61.491747	21.837152	108.5	70.6	0.085
67	67.05615459	Excellent for irrigation	2016-06-02	B-Daugava MS	56.914538	24.167233	266.3	173.1	0.1
68	67.02089165	Excellent for irrigation	2016-06-02	C-Daugava DS	56.937357	24.114167	270	175.4	0.1
69	66.97919393	Excellent for irrigation	2016-06-02	A-Daugava US	56.91348	24.169145	274.05	178.15	0.1
70	54.18309638	Slight to moderate toxic	2016-06-02	LIELUPE	56.973479	23.861068	837.8421053	536.1578947	0.4
71	28.73866667	Severe for irrigation	2016-03-25	C-Manoa ST	21.311147	-157.808813	17.26666667	11.26666667	0.006666667
72	5.631484209	Severe for irrigation	2016-03-27	F-Alawai	21.277616	-157.81996	29161.90476	18061.90476	17.98095238
73	5.604320078	Severe for irrigation	2016-03-27	K-Alawai	21.287292	-157.8321	30219.04762	18457.14286	18.71428571
74	5.410571101	Severe for irrigation	2016-03-27	L-Alawai	21.288718	-157.834047	34871.42857	21276.19048	21.92857143
75	5.111111111	Severe for irrigation	2016-03-24	B-Nuuanu-ST-DS	21.313273	-157.864874	41850	25633.33333	26.74166667
76	5.063655703	Severe for irrigation	2016-03-27	J-Alawai	21.28593	-157.83054	43142.85714	26323.80952	27.75238095
77	4.989003436	Severe for irrigation	2016-03-27	M-Alawai	21.287627	-157.83978	44985	27410	29.085
78	4.962199313	Severe for irrigation	2016-03-27	E-Alawai	21.277997	-157.821242	45571.42857	27800	29.5
79	4.960028938	Severe for irrigation	2016-03-27	O-Alawai	21.284561	-157.839613	45647.36842	27831.57895	29.58421053
80	4.959106529	Severe for irrigation	2016-03-27	N-Alawai	21.28756	-157.843219	45645	27845	29.55

(stdin):

Fig. 6.53 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of irrigation (Query: irrigation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Excellent for irrigation, Moderate hazard for irrigation, and Hazard for irrigation)).

6.5.3 Experimental results of Water-quality Analysis System with Semantic-ordering functions on Multiple parameters for local analysis

As the result from sampling water quality data, this study analyzed the water quality with semantic-ordering functions on multiple parameters by several points along Chaophrya river in Thailand. The analysis analyzed from the lowest to the highest concentration in a result of the worst to the best water-quality. In the parameter analysis by using multiple parameters in 7 contexts:

- The results of water-quality with semantic-ordering functions for the context of agriculture. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as suddenly toxic for agriculture was detected at Samut Phrakan 4 points and Bangkok 4 points. For the critical levels of health and hygiene impact attributable to water quality in unfit for agriculture were detected at Samut Phrakan 2 points, Nonthaburi 1 point, and Bangkok 2 points. The critical levels of health and hygiene impact attributable to water quality as the Satisfactory for livestock were detected at Samut Phrakan 2 points, Nonthaburi 2 points, and Bangkok 5 points. The critical levels of health and hygiene impact attributable to water quality as the hazard for the high crop were detected at Bangkok 1 point, Ang Thong 1 point, and Sing Buri 1 point. The critical levels of health and hygiene impact attributable to water quality as the hazard for the sensitive crop were detected at Sing Buri 7 points, Chai Nat 5 points, Phra Nakhon Si Ayutthaya 3 points. Pathum Thani 2 points, Nakhon Sawan 1 point, and Ang Thong 3 points etc. For the first to third ranking are Samut Prakan (June 27, 2013, February 17, 2014) and it showed to the Suddenly toxic for agriculture. The result is shown in Figures 6.54 and 6.61.

- The results of water-quality with semantic-ordering functions for the context of aquatic life. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as all aqualic life extinction life were detected at Bangkok 10 points, Phra Nakhon Si Ayutthaya 1 point, Samut Prakan 7 points, Nanthaburi 7 points, and Phrathum Thani 4 points etc. From the table in the first row to third row ranking were Bangkok (February 13, 2012 and June 27, 2013), and Phra Nakhon Si Ayutthaya (December 18, 2012) and it showed all aquatic life extinction. The result is shown in Figures 6.55 and 6.62.

- The results of water-quality with semantic-ordering functions for the context of drinking. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality in unfit for drinking were detected at Samut Prakan 13 points, Bangkok 12 points, Nanthaburi 3 points, and Phra Nakhon Si Ayutthaya 2 points. For the levels of health and hygiene impact attributable to water quality as hazard and chronic toxic for drinking were detected at Bangkok 2 points, Nanthaburi 3 points, Samut Prakan 2 points, Sing Buri 9 points, Pathum Thani 4 points, Phra Nakhon Si Ayutthaya 3 points, And Thong 3 points, and Chai Nat 3 point etc. From the table in the first row to third row ranking was detected several points at Samut Prakan (May 14, 2012 and February 18, 2013) and it showed hazard and chronic toxic for drinking. The result is shown in Figures 6.56 and 6.63.

- The results of water-quality with semantic-ordering functions for the context of fish. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as a hazard for fish and salmon dying were detected at Sing Buri 2 points and Phra Nakhon Si Ayutthay 1 point. For the levels of health and hygiene impact attributable to water quality as optimum for fish and shrimp were detected at Pathum Thani 1 point, Nanthaburi 2 points, Bangkok 1 point, Sing Buri 1 point, Ang Thong 3 points, Chai Nat 2 points, and Nakhon Sawan 2 points etc. From the table in the first row to third row ranking were detected at Sing Buri and Phra Nakhon Si Ayutthaya (February 18, 2013, June 28, 2013) and it showed hazard for fish and salmon dying. The result is shown in Figures 6.57 and 6.64.

- The results of water-quality with semantic-ordering functions for the context of industry. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality in unfit for industrial processes were detected at Samut Prakan 13 points, Bangkok 8 points, and Nanthaburi 3 points. For the levels of health and hygiene impact attributable to water quality in hightly corrosive scaling and fouling were detected at Chai Nat 2 points, Sing Buri 2 points, Nonthaburi 1 point, Pathum Thani 3 points, Chai Nat 2 points, and Phra Nakhon Si Ayutthaya 1 point etc. For the levels of health and hygiene impact attributable to water quality as slighly corrosive scaling and fouling were detected at Ang Thong 2 points, Phra Nakhon Si Ayutthaya 2 points, Sing Buri 6 points, From the table in the first row to third row ranking was detected in sevearal point at Samut

Prakan (February 17, 2014, May 19, 2013) and it showed unfit for industrial process. The result is shown in Figures 6.58 and 6.65.

- The results of water-quality with semantic-ordering functions for the context of irrigation. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as Hazard for irrigation were detected at Bangkok 10 points, Samut Prakan 9 points, Nonthaburi 3 points, Ang Thong 4 points, Sing Buri 3 points, and Pathum Thanin 1 point etc. For the levels of health and hygiene impact attributable to water quality in moderate hazard for irrigation were detected at Sing Buri 10 points, Chai Nat 4 points, Ang Thong 4 points, Pathum Thani 2 points, and Phra Nakan Si Ayutthaya 2 points etc. From the table in the first row to third row ranking was detected in sevearal point at Bangkok (February 17, 2014, June 27, 2013) and it showed Hazard for irrigation. The result is shown in Figures 6.59 and 6.66.

- The results of water-quality with semantic-ordering functions for the context of recreation. From the results of semantic ordering, the critical levels of health and hygiene impact attributable to water quality as strongly risk of illness were detected at Samut Prakanand and Nakhon Sawan. For the critical levels of health and hygiene impact attributable to water quality in critical risk of illness were detected Chai Nat 2 points, Bangkok 11 points, Nonthaburi 5 points, Samut Prakan 5 points, Nakhon Sawan 2 points, Phra Nakan Si Ayutthaya 1 point, and Sing Buri 1 point etc. From the table in the first to third row ranking were detected at Samut Prakan (June 27, 2013), Nakhon Sawan (August 13, 2013), and Chai Nat (February 21, 2013), which are shown strongly risk of illness. The result is shown in Figures 6.60 and 6.67.

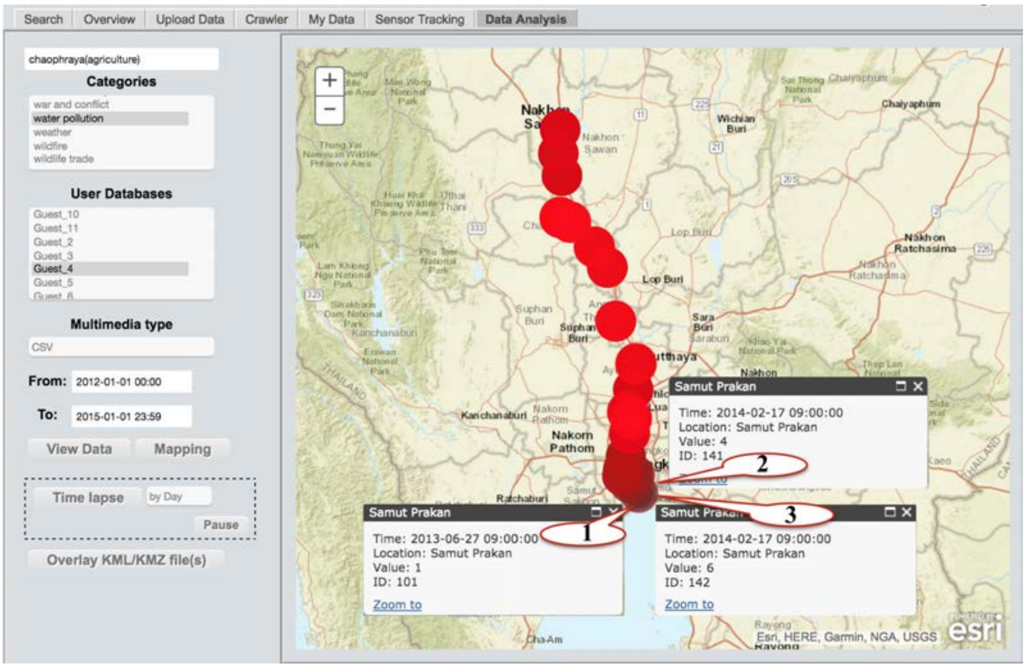


Fig. 6.54 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of agriculture on 5D World Map System (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).

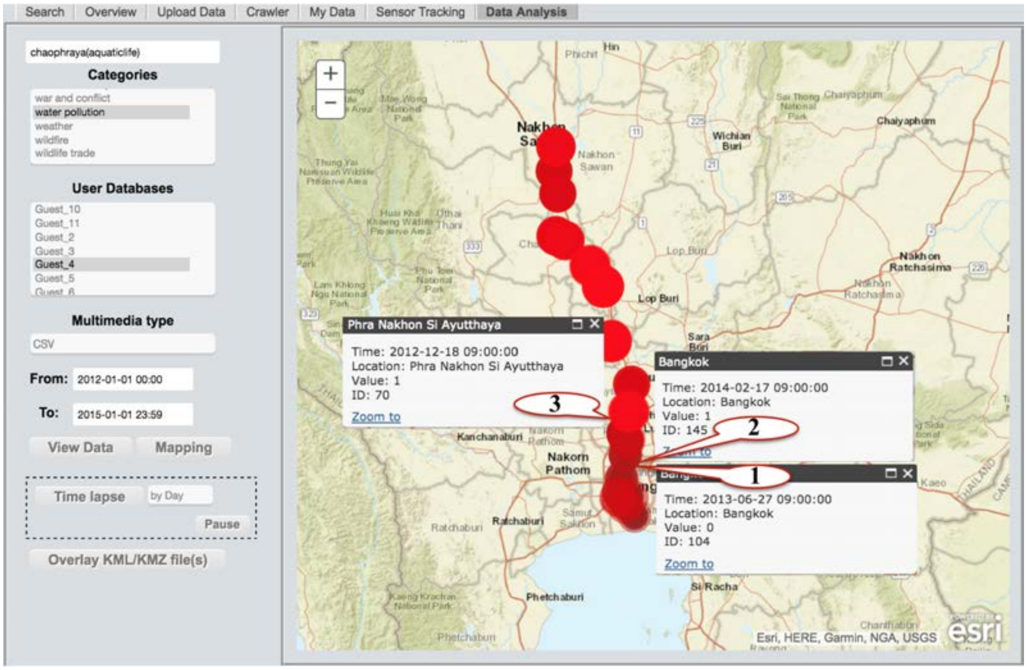


Fig. 6.55 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of aquatic life on 5D World Map System (Query: aquatic life, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, and All aquatic life extinction)).

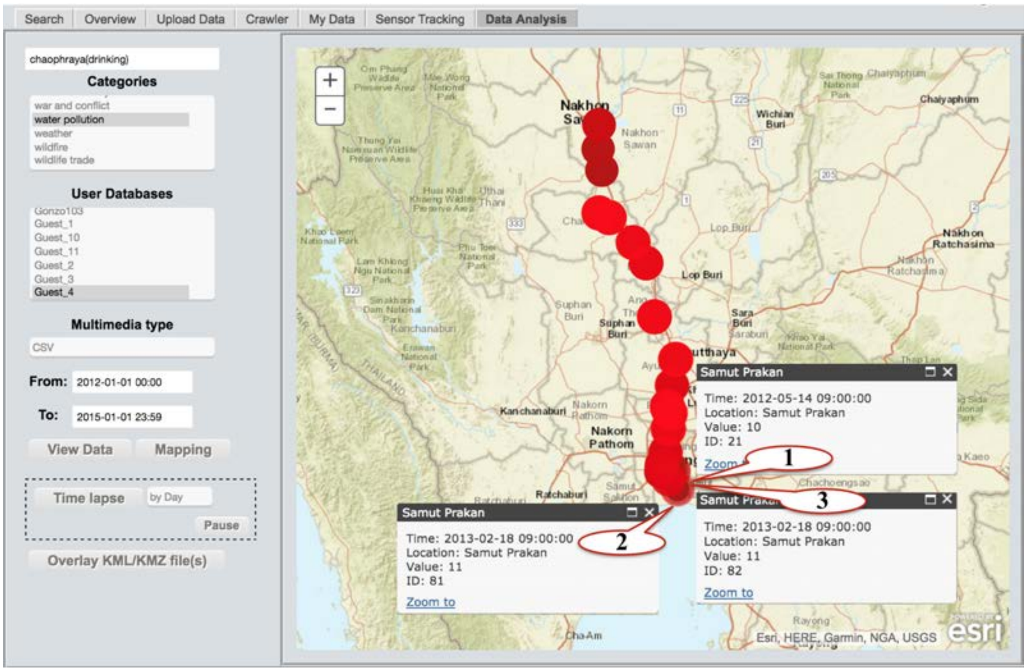


Fig. 6.56 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of drinking on 5D World Map System (Query: drinking, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Optimum for drinking, Hazard and chronic toxic for drinking, and Unfit and toxic for drinking)).

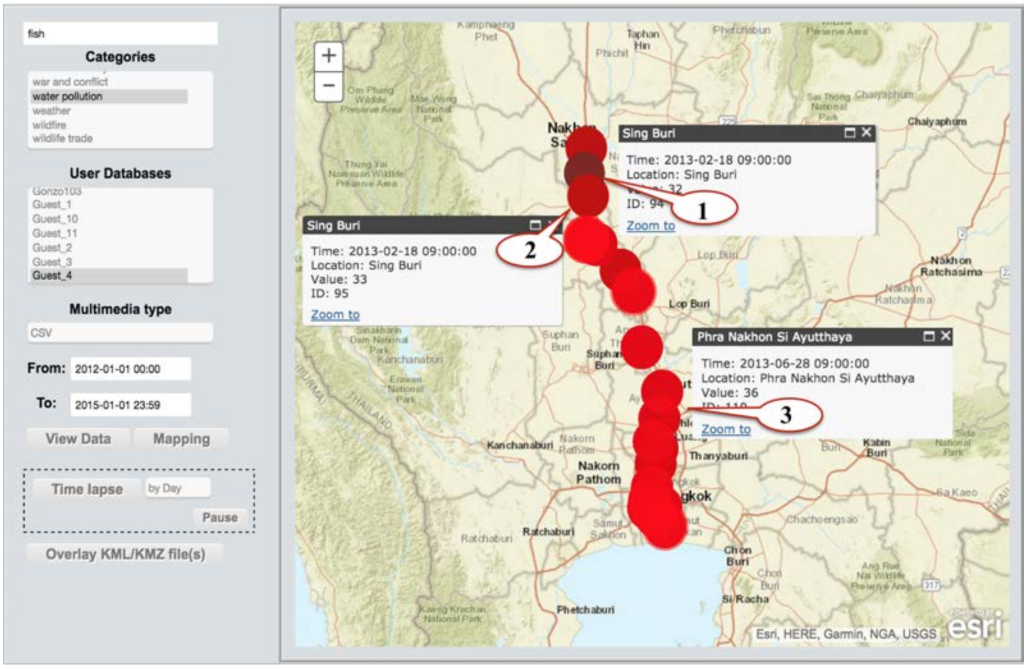


Fig. 6.57 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of fish on 5D World Map System (Query: fish, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant for fish, Optimum for fish and shrimp, Bacteria and plankton being disappear, Hazard for fish and salmon dying, and All fish extinction)).

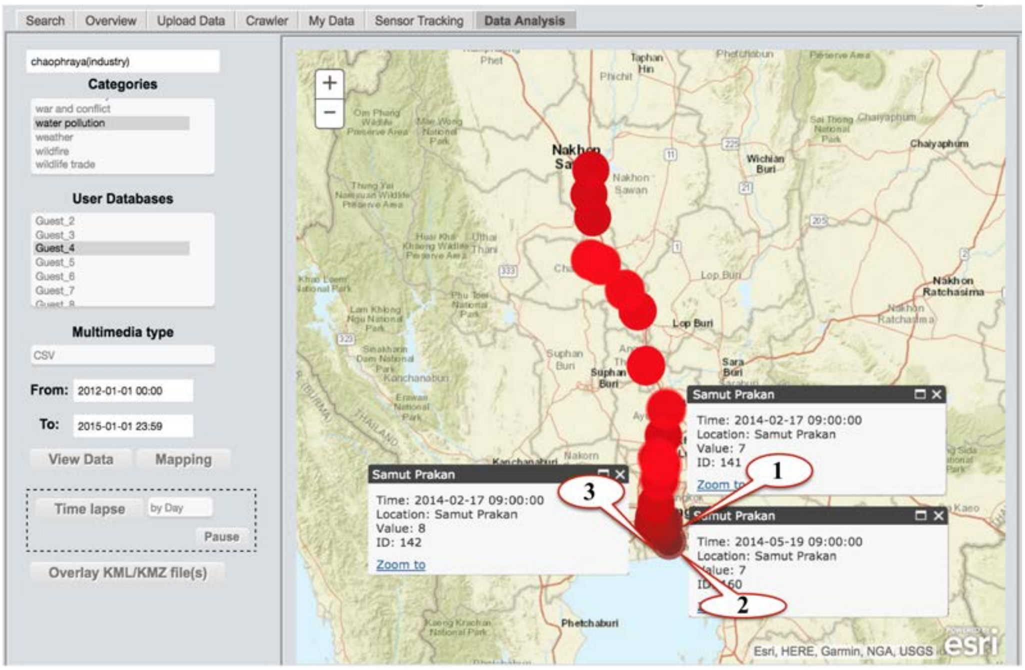


Fig. 6.58 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of industry on 5D World Map System (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).

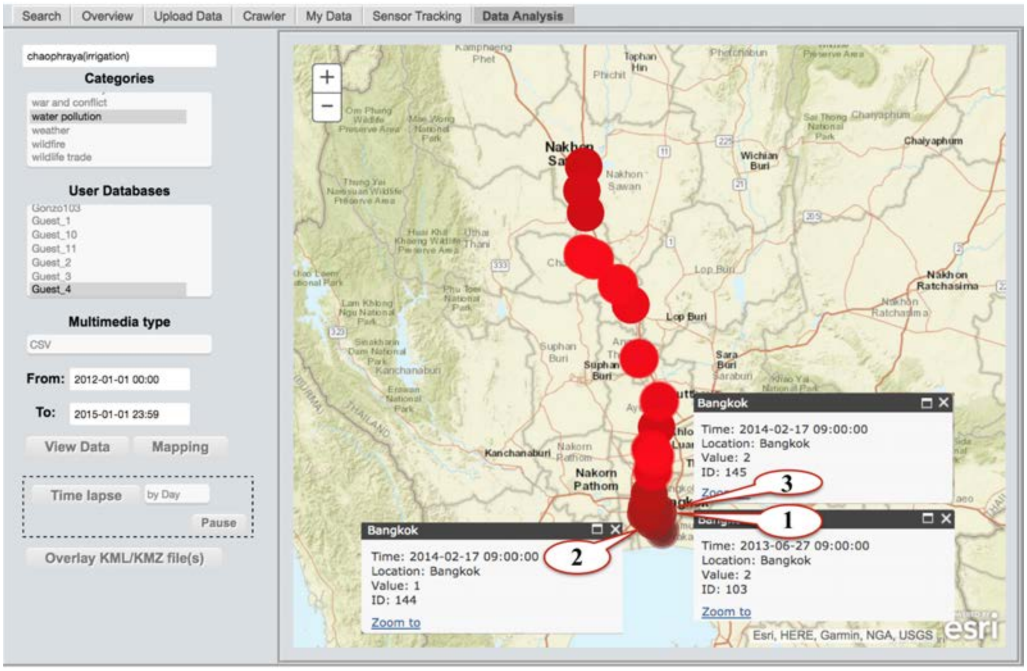


Fig. 6.59 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of irrigation on 5D World Map System (Query: irrigation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Excellent for irrigation, Moderate hazard for irrigation, and Hazard for irrigation)).

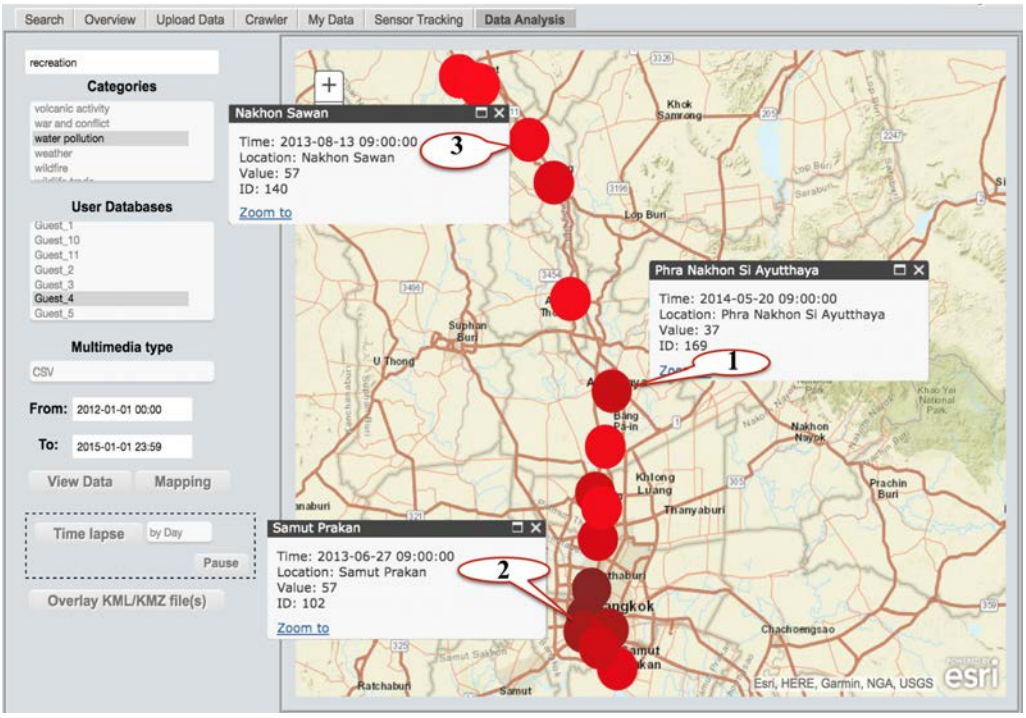


Fig. 6.60 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for the context of recreation on 5D World Map System (Query: recreation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Little risk of illness, Moderately risk of illness, Critical risk of illness, Strongly risk of illness, and Excessively risk of illness)).

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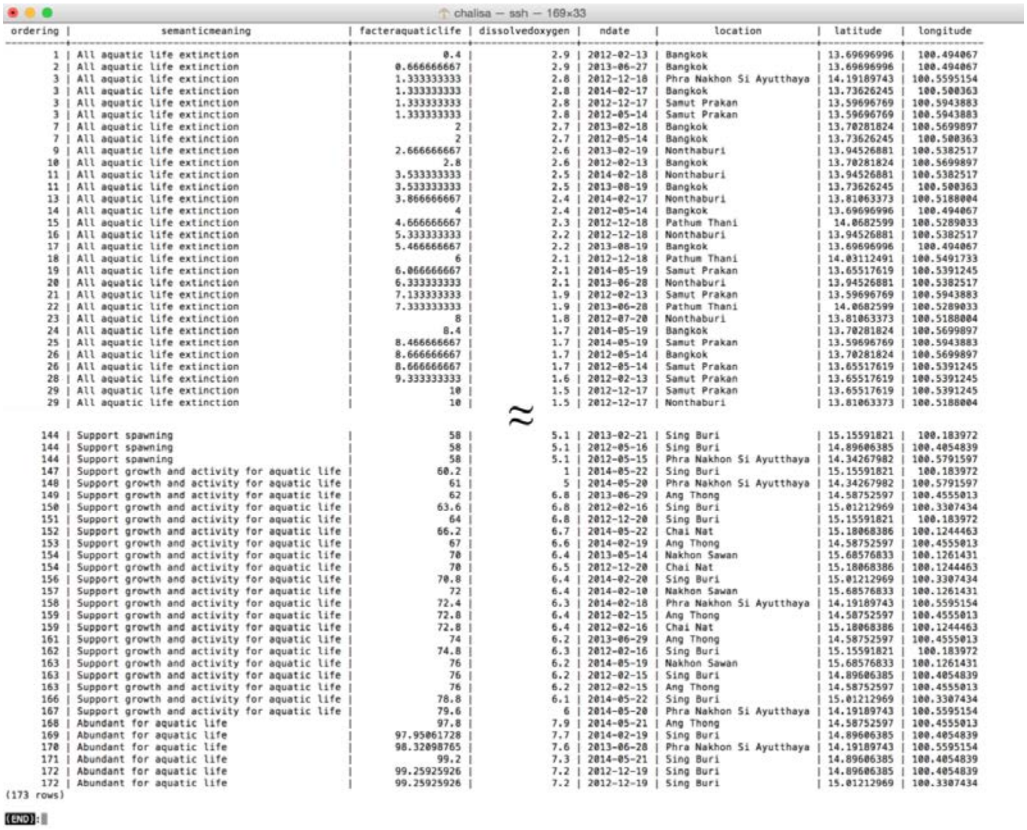
ordering	semanticmeaning	facteragriculture	conductivity	totaldissolvedsolid	salinity	ndate	location	latitude	longitude
1	Suddenly toxic for agriculture	1.592397423	28100	18827	16.8	2013-06-27	Samut Prakan	13.59696769	100.5943883
2	Suddenly toxic for agriculture	4.18779161	36100	24187	23	2014-02-17	Samut Prakan	13.59696769	100.5943883
3	Suddenly toxic for agriculture	6.239879954	31100	20837	19.4	2014-02-17	Samut Prakan	13.65517619	100.5391245
4	Suddenly toxic for agriculture	7.661276266	25000	16750	15	2014-05-19	Samut Prakan	13.59696769	100.5943883
5	Suddenly toxic for agriculture	7.785335758	27300	18291	16.8	2014-02-17	Bangkok	13.70281824	100.5699897
6	Suddenly toxic for agriculture	10.24767096	18200	12194	10.8	2013-06-27	Bangkok	13.70281824	100.5699897
7	Suddenly toxic for agriculture	10.36961482	20900	14003	12.6	2014-02-17	Bangkok	13.69696996	100.494067
8	Suddenly toxic for agriculture	11.86072878	17200	11524	10.2	2014-02-17	Bangkok	13.73626245	100.500363
9	Unfit for agriculture	13.42700155	16000	10720	9	2014-05-19	Samut Prakan	13.65517619	100.5391245
10	Unfit for agriculture	18.07989148	20600	13802	2.3	2013-06-27	Samut Prakan	13.65517619	100.5391245
11	Unfit for agriculture	19.43592091	19000	12730	1.2	2012-12-17	Samut Prakan	13.59696769	100.5943883
12	Unfit for agriculture	20.27124103	18000	11193.9	1	2012-05-14	Samut Prakan	13.59696769	100.5943883
13	Unfit for agriculture	20.44792969	12200	8174	6.8	2014-02-17	Nonthaburi	13.81063373	100.5188004
14	Unfit for agriculture	20.5812376	12000	8040	7	2014-05-19	Bangkok	13.70281824	100.5699897
15	Unfit for agriculture	24.39940744	16000	10720	8	2013-02-18	Samut Prakan	13.59696769	100.5943883
16	Unfit for agriculture	24.92154605	10300	6901	5.7	2013-06-27	Bangkok	13.69696996	100.494067
17	Hazard for poultry	31.99228516	11000	6469.2	0.6	2012-05-14	Samut Prakan	13.65517619	100.5391245
18	Hazard for poultry	33.15526961	6900	4623	4	2013-02-18	Samut Prakan	13.65517619	100.5391245
19	Hazard for poultry	36.03165391	6900	4623	0.4	2012-12-17	Samut Prakan	13.65517619	100.5391245
20	Satisfactory for livestock	37.85288173	6350	4254.5	1.71	2013-06-27	Bangkok	13.73626245	100.500363
21	Satisfactory for livestock	41.04903442	4400	3099.4	0.2	2012-05-14	Bangkok	13.70281824	100.5699897
22	Satisfactory for livestock	41.06574418	4360	2954.8	0.26	2012-02-13	Samut Prakan	13.59696769	100.5943883
23	Satisfactory for livestock	41.33490385	2820	1889.4	1.3	2014-02-18	Nonthaburi	13.94526881	100.5382517
24	Satisfactory for livestock	41.49001623	2100	1407	0.1	2014-05-19	Bangkok	13.69696996	100.494067
25	Satisfactory for livestock	42.18469806	3520	2358.4	1.7	2013-06-27	Nonthaburi	13.81063373	100.5188004
26	Satisfactory for livestock	44.29911844	1900	1273	0.1	2012-12-17	Bangkok	13.70281824	100.5699897
27	Satisfactory for livestock	44.83419349	2200	1474	1	2013-02-18	Bangkok	13.70281824	100.5699897
28	Hazard for high tolerance crop	52.00581865	1100	737	0	2014-05-19	Bangkok	13.73626245	100.500363
29	Hazard for high tolerance crop	52.06153148	1070	716.9	1.1	2012-12-19	Sing Buri	14.89606385	100.4054839
29	Hazard for high tolerance crop	52.06153148	1070	716.9	1.1	2013-06-29	Ang Thong	14.58752597	100.4555013
				≈					
147	Hazard for sensitive crop	80.46510067	125	118.3	0	2012-02-16	Sing Buri	15.15591821	100.183972
148	Hazard for sensitive crop	80.51879195	125	115.1	0	2012-02-16	Chai Nat	15.18068386	100.1244463
149	Hazard for sensitive crop	80.5297619	147	129	0	2012-05-15	Chai Nat	15.42268813	100.138766
150	Hazard for sensitive crop	80.55486577	133	89.11	0	2013-06-30	Chai Nat	15.18068386	100.1244463
151	Hazard for sensitive crop	80.56241611	130	97.6	0	2012-07-23	Sing Buri	15.01212969	100.3307434
152	Hazard for sensitive crop	80.7385986	130	87.1	0	2013-02-21	Sing Buri	15.15591821	100.183972
153	Hazard for sensitive crop	80.88690476	130	158.5	0	2012-05-15	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
154	Hazard for sensitive crop	81.04479866	125	83.75	0	2013-08-20	Pathum Thani	14.0682599	100.5289033
155	Hazard for sensitive crop	81.08928571	127	152	0	2013-08-13	Nakhon Sawan	15.68576833	100.1261431
156	Hazard for sensitive crop	81.16728188	123	82.41	0	2013-08-20	Pathum Thani	14.03112491	100.5491733
157	Hazard for sensitive crop	81.25704698	120	86	0	2012-07-23	Chai Nat	15.18068386	100.1244463
158	Hazard for sensitive crop	82.08590604	108	72.36	0	2013-08-20	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
159	Hazard for sensitive crop	82.69832215	98	65.66	0	2013-08-21	Sing Buri	14.89606385	100.4054839
160	Hazard for sensitive crop	82.75956376	97	64.99	0	2013-08-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
160	Hazard for sensitive crop	82.75956376	97	64.99	0	2013-08-22	Sing Buri	15.01212969	100.3307434
162	Hazard for sensitive crop	82.82080537	96	64.32	0	2013-08-22	Sing Buri	15.15591821	100.183972
162	Hazard for sensitive crop	82.82080537	96	64.32	0	2013-08-22	Chai Nat	15.18068386	100.1244463
162	Hazard for sensitive crop	82.82080537	96	64.32	0	2013-08-21	Ang Thong	14.58752597	100.4555013
165	Hazard for sensitive crop	82.88204698	95	63.65	0	2013-08-21	Ang Thong	14.58752597	100.4555013
166	Hazard for sensitive crop	83.43322148	86	57.62	0	2014-02-19	Sing Buri	14.89606385	100.4054839
167	Excellent for agriculture	87.53073732	67	44.89	0	2014-02-19	Ang Thong	14.58752597	100.4555013
168	Excellent for agriculture	88.60132364	60	40.2	0	2014-02-20	Chai Nat	15.18068386	100.1244463
169	Excellent for agriculture	88.75426454	59	39.53	0	2014-02-20	Sing Buri	15.15591821	100.183972
170	Excellent for agriculture	92.30985222	13	151.2	0	2012-05-17	Chai Nat	15.18068386	100.1244463
171	Excellent for agriculture	94.02424207	13	146.9	0	2012-05-17	Sing Buri	15.15591821	100.183972
172	Excellent for agriculture	94.03263134	13	146.6	0	2012-05-17	Sing Buri	15.01212969	100.3307434
173	Excellent for agriculture	97.01157911	18.4	12.328	0	2014-02-18	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
174	Excellent for agriculture	97.97391273	1.48	0.9916	0.06	2013-06-28	Nonthaburi	13.94526881	100.5382517
175	Excellent for agriculture	98.30401461	1.28	0.8576	0.05	2013-06-28	Pathum Thani	14.0682599	100.5289033
176	Excellent for agriculture	98.64061306	1.04	0.6968	0.04	2013-06-28	Pathum Thani	14.03112491	100.5491733

(176 rows)

(END):

Fig. 6.61 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of agriculture (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).



ordering	semanticmeaning	facteraquaticlife	dissolvedoxygen	ndate	location	latitude	longitude
1	All aquatic life extinction	0.4	2.9	2012-02-13	Bangkok	13.69696996	100.494067
2	All aquatic life extinction	0.666666667	2.9	2013-06-27	Bangkok	13.69696996	100.494067
3	All aquatic life extinction	1.333333333	2.8	2012-12-18	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
3	All aquatic life extinction	1.333333333	2.8	2014-02-17	Bangkok	13.73626245	100.500363
3	All aquatic life extinction	1.333333333	2.8	2012-12-17	Samut Prakan	13.59696769	100.5943883
3	All aquatic life extinction	1.333333333	2.8	2012-05-14	Samut Prakan	13.59696769	100.5943883
7	All aquatic life extinction	2	2.7	2013-02-18	Bangkok	13.70281824	100.5699897
7	All aquatic life extinction	2	2.7	2012-05-14	Bangkok	13.73626245	100.500363
9	All aquatic life extinction	2.666666667	2.6	2013-02-19	Nonthaburi	13.94526881	100.5382517
10	All aquatic life extinction	2.8	2.6	2012-02-13	Bangkok	13.70281824	100.5699897
11	All aquatic life extinction	3.533333333	2.5	2014-02-18	Nonthaburi	13.94526881	100.5382517
11	All aquatic life extinction	3.533333333	2.5	2013-08-19	Bangkok	13.73626245	100.500363
13	All aquatic life extinction	3.866666667	2.4	2014-02-17	Nonthaburi	13.81063373	100.5188004
14	All aquatic life extinction	4	2.4	2012-05-14	Bangkok	13.69696996	100.494067
15	All aquatic life extinction	4.666666667	2.3	2012-12-18	Pathum Thani	14.0682599	100.5289033
16	All aquatic life extinction	5.333333333	2.2	2012-12-18	Nonthaburi	13.94526881	100.5382517
17	All aquatic life extinction	5.466666667	2.2	2013-08-19	Bangkok	13.69696996	100.494067
18	All aquatic life extinction	6	2.1	2012-12-18	Pathum Thani	14.03112491	100.5491733
19	All aquatic life extinction	6.066666667	2.1	2014-05-19	Samut Prakan	13.65517619	100.5391245
20	All aquatic life extinction	6.333333333	2.1	2013-06-28	Nonthaburi	13.94526881	100.5382517
21	All aquatic life extinction	7.133333333	1.9	2012-02-13	Samut Prakan	13.59696769	100.5943883
22	All aquatic life extinction	7.333333333	1.9	2013-06-28	Pathum Thani	14.0682599	100.5289033
23	All aquatic life extinction	8	1.8	2012-07-20	Nonthaburi	13.81063373	100.5188004
24	All aquatic life extinction	8.4	1.7	2014-05-19	Bangkok	13.70281824	100.5699897
25	All aquatic life extinction	8.466666667	1.7	2014-05-19	Samut Prakan	13.59696769	100.5943883
26	All aquatic life extinction	8.666666667	1.7	2012-05-14	Bangkok	13.70281824	100.5699897
26	All aquatic life extinction	8.666666667	1.7	2012-05-14	Samut Prakan	13.65517619	100.5391245
28	All aquatic life extinction	9.333333333	1.6	2012-02-13	Samut Prakan	13.65517619	100.5391245
29	All aquatic life extinction	10	1.5	2012-12-17	Samut Prakan	13.65517619	100.5391245
29	All aquatic life extinction	10	1.5	2012-12-17	Nonthaburi	13.81063373	100.5188004
≈							
144	Support spawning	58	5.1	2013-02-21	Sing Buri	15.15591821	100.183972
144	Support spawning	58	5.1	2012-05-16	Sing Buri	14.89606385	100.4054839
144	Support spawning	58	5.1	2012-05-15	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
147	Support growth and activity for aquatic life	60.2	1	2014-05-22	Sing Buri	15.15591821	100.183972
148	Support growth and activity for aquatic life	61	5	2014-05-20	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
149	Support growth and activity for aquatic life	62	6.8	2013-06-29	Ang Thong	14.58752597	100.4555013
150	Support growth and activity for aquatic life	63.6	6.8	2012-02-16	Sing Buri	15.01212969	100.3307434
151	Support growth and activity for aquatic life	64	6.8	2012-12-20	Sing Buri	15.15591821	100.183972
152	Support growth and activity for aquatic life	66.2	6.7	2014-05-22	Chai Nat	15.18068386	100.1244463
153	Support growth and activity for aquatic life	67	6.6	2014-02-19	Ang Thong	14.58752597	100.4555013
154	Support growth and activity for aquatic life	70	6.4	2013-05-14	Nakhon Sawan	15.68576833	100.1261431
154	Support growth and activity for aquatic life	70	6.5	2012-12-20	Chai Nat	15.18068386	100.1244463
156	Support growth and activity for aquatic life	70.8	6.4	2014-02-20	Sing Buri	15.01212969	100.3307434
157	Support growth and activity for aquatic life	72	6.4	2014-02-10	Nakhon Sawan	15.68576833	100.1261431
158	Support growth and activity for aquatic life	72.4	6.3	2014-02-18	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
159	Support growth and activity for aquatic life	72.8	6.4	2012-02-15	Ang Thong	14.58752597	100.4555013
159	Support growth and activity for aquatic life	72.8	6.4	2012-02-16	Chai Nat	15.18068386	100.1244463
161	Support growth and activity for aquatic life	74	6.2	2013-06-29	Ang Thong	14.58752597	100.4555013
162	Support growth and activity for aquatic life	74.8	6.3	2012-02-16	Sing Buri	15.15591821	100.183972
163	Support growth and activity for aquatic life	76	6.2	2014-05-19	Nakhon Sawan	15.68576833	100.1261431
163	Support growth and activity for aquatic life	76	6.2	2012-02-15	Sing Buri	14.89606385	100.4054839
163	Support growth and activity for aquatic life	76	6.2	2012-02-15	Ang Thong	14.58752597	100.4555013
166	Support growth and activity for aquatic life	78.8	6.1	2014-05-22	Sing Buri	15.01212969	100.3307434
167	Support growth and activity for aquatic life	79.6	6	2014-05-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
168	Abundant for aquatic life	97.8	7.9	2014-05-21	Ang Thong	14.58752597	100.4555013
169	Abundant for aquatic life	97.95061728	7.7	2014-02-19	Sing Buri	14.89606385	100.4054839
170	Abundant for aquatic life	98.32098765	7.6	2013-06-28	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
171	Abundant for aquatic life	99.2	7.3	2014-05-21	Sing Buri	14.89606385	100.4054839
172	Abundant for aquatic life	99.25925926	7.2	2012-12-19	Sing Buri	14.89606385	100.4054839
172	Abundant for aquatic life	99.25925926	7.2	2012-12-19	Sing Buri	15.01212969	100.3307434

(173 rows)

(END):

Fig. 6.62 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of aquatic life (Query: aquatic life, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant aquatic life, Support growth and activity for aquatic life, Support spawning, Hazard for aquatic life, and All aquatic life extinction)).

chalisa — ssh — 181×33

ordering	semanticmeaning	facterdrinking	ph	conductivity	totaldissolvedsolid	ndate	location	latitude	longitude
1	Unfit and toxic for drinking	10.23809524	8.2	18000	11193.9	2012-05-14	Samut Prakan	13.59696769	100.5943883
2	Unfit and toxic for drinking	11.66666667	7.6	6900	4623	2013-02-18	Samut Prakan	13.65517619	100.5391245
2	Unfit and toxic for drinking	11.66666667	7.6	16000	10720	2013-02-18	Samut Prakan	13.59696769	100.5943883
4	Unfit and toxic for drinking	11.9047619	7.5	2100	1407	2014-05-19	Bangkok	13.69696996	100.494067
5	Unfit and toxic for drinking	12.11904762	7.4	36100	24187	2014-02-17	Samut Prakan	13.59696769	100.5943883
6	Unfit and toxic for drinking	12.14285714	7.4	2200	1474	2013-02-18	Bangkok	13.70281824	100.5699897
6	Unfit and toxic for drinking	12.14285714	7.4	11000	6469.2	2012-05-14	Samut Prakan	13.65517619	100.5391245
6	Unfit and toxic for drinking	12.14285714	7.4	19000	12730	2012-12-17	Samut Prakan	13.59696769	100.5943883
6	Unfit and toxic for drinking	12.14285714	7.4	16000	10720	2014-05-19	Samut Prakan	13.65517619	100.5391245
6	Unfit and toxic for drinking	12.14285714	7.4	25000	16750	2014-05-19	Samut Prakan	13.59696769	100.5943883
11	Unfit and toxic for drinking	12.38095238	7.3	6900	4623	2012-12-17	Samut Prakan	13.65517619	100.5391245
11	Unfit and toxic for drinking	12.38095238	7.3	12000	8040	2014-05-19	Bangkok	13.70281824	100.5699897
11	Unfit and toxic for drinking	12.38095238	7.3	4400	3099.4	2012-05-14	Bangkok	13.70281824	100.5699897
14	Unfit and toxic for drinking	12.61904762	7.2	2820	1889.4	2014-02-18	Nonthaburi	13.94526881	100.5382517
15	Unfit and toxic for drinking	12.64285714	7.2	3520	2358.4	2013-06-27	Nonthaburi	13.81063373	100.5188004
16	Unfit and toxic for drinking	12.66666667	7.2	31100	20837	2014-02-17	Samut Prakan	13.65517619	100.5391245
17	Unfit and toxic for drinking	12.69047619	7.2	27300	18291	2014-02-17	Bangkok	13.70281824	100.5699897
18	Unfit and toxic for drinking	12.73809524	7.2	18200	12194	2013-06-27	Bangkok	13.70281824	100.5699897
18	Unfit and toxic for drinking	12.73809524	7.2	6350	4254.5	2013-06-27	Bangkok	13.73626245	100.500363
20	Unfit and toxic for drinking	12.80952381	7.1	28100	18827	2013-06-27	Samut Prakan	13.59696769	100.5943883
21	Unfit and toxic for drinking	12.85714286	7.1	20600	13802	2013-06-27	Samut Prakan	13.65517619	100.5391245
22	Unfit and toxic for drinking	13.07142857	7	4360	2954.8	2012-02-13	Samut Prakan	13.59696769	100.5943883
22	Unfit and toxic for drinking	13.07142857	7	10300	6901	2013-06-27	Bangkok	13.69696996	100.494067
24	Unfit and toxic for drinking	13.0952381	7	1900	1273	2012-12-17	Bangkok	13.70281824	100.5699897
25	Unfit and toxic for drinking	13.52380952	6.8	20900	14003	2014-02-17	Bangkok	13.69696996	100.494067
26	Unfit and toxic for drinking	13.66666667	6.8	12200	8174	2014-02-17	Nonthaburi	13.81063373	100.5188004
27	Unfit and toxic for drinking	13.80952381	6.7	17200	11524	2014-02-17	Bangkok	13.73626245	100.500363
28	Unfit and toxic for drinking	19.29978625	8.6	1070	716.9	2013-06-28	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
29	Unfit and toxic for drinking	21.08550053	7.9	1070	716.9	2013-06-28	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
30	Unfit and toxic for drinking	21.98848118	7.2	1100	737	2014-05-19	Bangkok	13.73626245	100.500363
					≈				
147	Hazard and chronic toxic for drinking	41.29444444	6.8	380	254.6	2013-02-18	Bangkok	13.69696996	100.494067
148	Hazard and chronic toxic for drinking	41.59027778	6.5	250	267.5	2012-05-14	Nonthaburi	13.81063373	100.5188004
149	Hazard and chronic toxic for drinking	42.13069444	6.7	359	240.53	2013-08-19	Samut Prakan	13.59696769	100.5943883
150	Hazard and chronic toxic for drinking	42.14288107	7.1	135	90.45	2013-06-30	Sing Buri	15.15591821	100.183972
151	Hazard and chronic toxic for drinking	42.23283082	6.8	150	100.5	2014-05-22	Sing Buri	15.15591821	100.183972
152	Hazard and chronic toxic for drinking	42.46901173	6.5	140	108.1	2012-07-22	Sing Buri	14.89606385	100.4054839
153	Hazard and chronic toxic for drinking	43.20555556	6.7	270	215.4	2012-07-20	Samut Prakan	13.65517619	100.5391245
154	Hazard and chronic toxic for drinking	43.24722222	6.7	320	214.4	2013-02-18	Bangkok	13.73626245	100.500363
155	Hazard and chronic toxic for drinking	43.53500838	7.5	97	64.99	2013-08-22	Sing Buri	15.01212969	100.3307434
156	Hazard and chronic toxic for drinking	43.54288107	6.7	135	90.45	2013-08-20	Nonthaburi	13.94526881	100.5382517
157	Hazard and chronic toxic for drinking	43.74237856	7.6	86	57.62	2014-02-19	Sing Buri	14.89606385	100.4054839
158	Hazard and chronic toxic for drinking	43.81239531	6.7	140	88.1	2012-07-23	Sing Buri	15.15591821	100.183972
159	Hazard and chronic toxic for drinking	43.83433836	7.4	98	65.66	2013-08-21	Sing Buri	14.89606385	100.4054839
160	Hazard and chronic toxic for drinking	43.83567839	7.4	96	64.32	2013-08-22	Sing Buri	15.15591821	100.183972
161	Hazard and chronic toxic for drinking	43.98425461	6.8	123	82.41	2013-08-20	Pathum Thani	14.03112491	100.5491733
162	Hazard and chronic toxic for drinking	44.04958124	6.8	125	83.75	2013-08-20	Pathum Thani	14.0682599	100.5289033
163	Hazard and chronic toxic for drinking	44.29430486	7	108	72.36	2013-08-20	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
164	Hazard and chronic toxic for drinking	44.33567839	7.3	96	64.32	2013-08-21	Ang Thong	14.58752597	100.4555013
165	Hazard and chronic toxic for drinking	44.43567839	7.2	96	64.32	2013-08-22	Chai Nat	15.18068386	100.1244463
166	Hazard and chronic toxic for drinking	44.69011725	6.5	120	86	2012-07-23	Chai Nat	15.18068386	100.1244463
167	Hazard and chronic toxic for drinking	44.75510888	7.7	67	44.89	2014-02-19	Ang Thong	14.58752597	100.4555013
168	Hazard and chronic toxic for drinking	45.10301508	7.1	95	63.65	2013-08-21	Ang Thong	14.58752597	100.4555013
169	Hazard and chronic toxic for drinking	45.50167504	6.9	97	64.99	2013-08-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
170	Hazard and chronic toxic for drinking	46.22244556	7.3	66	44.22	2014-02-20	Sing Buri	15.01212969	100.3307434
171	Hazard and chronic toxic for drinking	46.45979899	7.4	60	40.2	2014-02-20	Chai Nat	15.18068386	100.1244463
172	Hazard and chronic toxic for drinking	46.86046901	7.3	59	39.53	2014-02-20	Sing Buri	15.15591821	100.183972
173	Hazard and chronic toxic for drinking	49.32767169	7.3	18.4	12.328	2014-02-18	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
174	Hazard and chronic toxic for drinking	50.50034171	7.3	1.48	0.9916	2013-06-28	Nonthaburi	13.94526881	100.5382517
175	Hazard and chronic toxic for drinking	50.69663652	7.3	1.04	0.6968	2013-06-28	Pathum Thani	14.03112491	100.5491733
176	Hazard and chronic toxic for drinking	50.81380905	7.2	1.28	0.8576	2013-06-28	Pathum Thani	14.0682599	100.5289033

(176 rows)

(END):

Fig. 6.63 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of drinking (Query: drinking, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Optimum for drinking, Hazard and chronic toxic for drinking, and Unfit and toxic for drinking)).

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chalisav — เทอร์มินัล — ssh — 140×35
ordering |        semanticmeaning          | facterfish  | ph  |   ndate    |          location          |  latitude   |  longitude
---------+---------------------------------+-------------+-----+------------+----------------------------+-------------+-------------
       1 | Hazard for fish and salmon dying | 32.72727273 |   9 | 2013-02-18 | Sing Buri                  | 14.89606385 | 100.4054839
       2 | Hazard for fish and salmon dying | 33.63636364 | 8.9 | 2013-02-18 | Sing Buri                  | 15.01212969 | 100.3307434
       3 | Hazard for fish and salmon dying | 36.09090909 | 8.6 | 2013-06-28 | Phra Nakhon Si Ayutthaya   | 14.19189743 | 100.5595154
       4 | Optimum for fish and shrimp      |          65 | 6.3 | 2012-07-21 | Pathum Thani               | 14.03112491 | 100.5491733
       4 | Optimum for fish and shrimp      |          65 | 6.3 | 2012-07-20 | Bangkok                    | 13.70281824 | 100.5699897
       4 | Optimum for fish and shrimp      |          65 | 5.9 | 2012-12-17 | Nonthaburi                 | 13.81063373 | 100.5188004
       4 | Optimum for fish and shrimp      |          65 | 6.3 | 2012-07-23 | Sing Buri                  | 15.01212969 | 100.3307434
       8 | Optimum for fish and shrimp      |          75 | 6.1 | 2012-07-22 | Ang Thong                  | 14.58752597 | 100.4555013
       8 | Optimum for fish and shrimp      |          75 | 6.1 | 2013-02-18 | Nonthaburi                 | 13.81063373 | 100.5188004
      10 | Optimum for fish and shrimp      | 78.18181818 | 8.4 | 2014-05-21 | Ang Thong                  | 14.58752597 | 100.4555013
      11 | Optimum for fish and shrimp      | 79.09090909 | 8.3 | 2012-05-16 | Ang Thong                  | 14.58752597 | 100.4555013
      12 | Optimum for fish and shrimp      |       79.75 | 8.1 | 2012-02-13 | Chai Nat                   | 15.42268813 |  100.138766
      12 | Optimum for fish and shrimp      |       79.75 | 8.1 | 2012-05-15 | Chai Nat                   | 15.42268813 |  100.138766
      14 | Optimum for fish and shrimp      |      79.875 | 8.1 | 2013-05-14 | Nakhon Sawan               | 15.68576833 | 100.1261431
      14 | Optimum for fish and shrimp      |      79.875 | 8.1 | 2012-05-15 | Nakhon Sawan               | 15.54754128 | 100.1170992
      16 | Abundant for fish                |       80.25 | 8.1 | 2012-02-13 | Nakhon Sawan               | 15.54754128 | 100.1170992
      17 | Abundant for fish                | 80.27272727 | 8.2 | 2012-05-15 | Nakhon Sawan               | 15.68576833 | 100.1261431
      18 | Abundant for fish                |        80.5 | 8.1 | 2013-05-14 | Chai Nat                   | 15.42268813 |  100.138766
      19 | Abundant for fish                |       81.25 |   8 | 2012-05-17 | Sing Buri                  | 15.15591821 |  100.183972
      19 | Abundant for fish                |       81.25 |   8 | 2013-02-21 | Sing Buri                  | 15.15591821 |  100.183972
      19 | Abundant for fish                |       81.25 |   8 | 2013-02-19 | Pathum Thani               |  14.0682599 | 100.5289033
      19 | Abundant for fish                |       81.25 |   8 | 2013-02-19 | Pathum Thani               | 14.03112491 | 100.5491733
      19 | Abundant for fish                |       81.25 |   8 | 2014-05-21 | Sing Buri                  | 14.89606385 | 100.4054839
      19 | Abundant for fish                |       81.25 |   8 | 2012-05-17 | Chai Nat                   | 15.18068386 | 100.1244463
      19 | Abundant for fish                |       81.25 |   8 | 2012-05-17 | Sing Buri                  | 15.01212969 | 100.3307434
      26 | Abundant for fish                |      81.375 |   8 | 2012-02-13 | Nakhon Sawan               | 15.68576833 | 100.1261431
      27 | Abundant for fish                |        81.5 |   8 | 2013-08-13 | Nakhon Sawan               | 15.68576833 | 100.1261431
      27 | Abundant for fish                |        81.5 |   8 | 2013-08-13 | Nakhon Sawan               | 15.54754128 | 100.1170992
      29 | Abundant for fish                |       81.75 |   8 | 2013-08-13 | Chai Nat                   | 15.42268813 |  100.138766
      29 | Abundant for fish                |       81.75 |   8 | 2012-11-05 | Nakhon Sawan               | 15.68576833 | 100.1261431
      31 | Abundant for fish                |          82 | 7.9 | 2012-11-05 | Chai Nat                   | 15.42268813 |  100.138766
      32 | Abundant for fish                |      82.125 | 7.9 | 2012-07-07 | Nakhon Sawan               | 15.54754128 | 100.1170992
                                                               ≈
     122 | Abundant for fish                |      94.125 |   7 | 2012-02-14 | Pathum Thani               | 14.03112491 | 100.5491733
     123 | Abundant for fish                |       94.25 |   7 | 2012-02-16 | Sing Buri                  | 15.01212969 | 100.3307434
     124 | Abundant for fish                |      94.625 | 6.9 | 2013-08-19 | Nonthaburi                 | 13.81063373 | 100.5188004
     125 | Abundant for fish                |          95 | 6.9 | 2013-02-18 | Ang Thong                  | 14.58752597 | 100.4555013
     125 | Abundant for fish                |          95 | 6.9 | 2012-05-14 | Bangkok                    | 13.69696996 |  100.494067
     127 | Abundant for fish                |      95.125 | 6.9 | 2013-08-20 | Phra Nakhon Si Ayutthaya   | 14.19189743 | 100.5595154
     128 | Abundant for fish                |       95.75 | 6.8 | 2012-02-14 | Nonthaburi                 | 13.94526881 | 100.5382517
     128 | Abundant for fish                |       95.75 | 6.8 | 2012-02-13 | Bangkok                    | 13.70281824 | 100.5699897
     128 | Abundant for fish                |       95.75 | 6.8 | 2012-02-13 | Nonthaburi                 | 13.81063373 | 100.5188004
     131 | Abundant for fish                |          96 | 6.8 | 2013-08-20 | Pathum Thani               | 14.03112491 | 100.5491733
     131 | Abundant for fish                |          96 | 6.8 | 2014-02-17 | Bangkok                    | 13.69696996 |  100.494067
     133 | Abundant for fish                |      96.125 | 6.8 | 2012-02-13 | Bangkok                    | 13.73626245 |  100.500363
     134 | Abundant for fish                |       96.25 | 6.8 | 2012-07-20 | Bangkok                    | 13.73626245 |  100.500363
     134 | Abundant for fish                |       96.25 | 6.8 | 2013-02-18 | Bangkok                    | 13.69696996 |  100.494067
     134 | Abundant for fish                |       96.25 | 6.8 | 2014-02-10 | Nakhon Sawan               | 15.68576833 | 100.1261431
     134 | Abundant for fish                |       96.25 | 6.8 | 2014-05-22 | Sing Buri                  | 15.15591821 |  100.183972
     138 | Abundant for fish                |       96.75 | 6.8 | 2014-02-17 | Nonthaburi                 | 13.81063373 | 100.5188004
     138 | Abundant for fish                |       96.75 | 6.8 | 2013-08-20 | Pathum Thani               |  14.0682599 | 100.5289033
     140 | Abundant for fish                |      97.375 | 6.7 | 2013-08-19 | Samut Prakan               | 13.59696769 | 100.5943883
     140 | Abundant for fish                |      97.375 | 6.7 | 2012-02-13 | Samut Prakan               | 13.65517619 | 100.5391245
     140 | Abundant for fish                |      97.375 | 6.7 | 2012-02-13 | Bangkok                    | 13.69696996 |  100.494067
     140 | Abundant for fish                |      97.375 | 6.7 | 2013-08-20 | Nonthaburi                 | 13.94526881 | 100.5382517
     144 | Abundant for fish                |        97.5 | 6.7 | 2012-07-20 | Samut Prakan               | 13.65517619 | 100.5391245
     144 | Abundant for fish                |        97.5 | 6.7 | 2012-05-14 | Bangkok                    | 13.73626245 |  100.500363
     144 | Abundant for fish                |        97.5 | 6.7 | 2013-02-18 | Bangkok                    | 13.73626245 |  100.500363
     144 | Abundant for fish                |        97.5 | 6.7 | 2014-02-17 | Bangkok                    | 13.73626245 |  100.500363
     144 | Abundant for fish                |        97.5 | 6.7 | 2012-07-21 | Pathum Thani               |  14.0682599 | 100.5289033
     144 | Abundant for fish                |        97.5 | 6.7 | 2012-07-23 | Sing Buri                  | 15.15591821 |  100.183972
     150 | Abundant for fish                |       97.75 | 6.7 | 2012-02-14 | Pathum Thani               |  14.0682599 | 100.5289033
     151 | Abundant for fish                |       98.75 | 6.6 | 2012-07-20 | Samut Prakan               | 13.59696769 | 100.5943883
     152 | Abundant for fish                |      99.375 | 6.6 | 2013-08-19 | Bangkok                    | 13.70281824 | 100.5699897
     152 | Abundant for fish                |      99.375 | 6.6 | 2013-08-19 | Bangkok                    | 13.73626245 |  100.500363
(153 rows)

(END):
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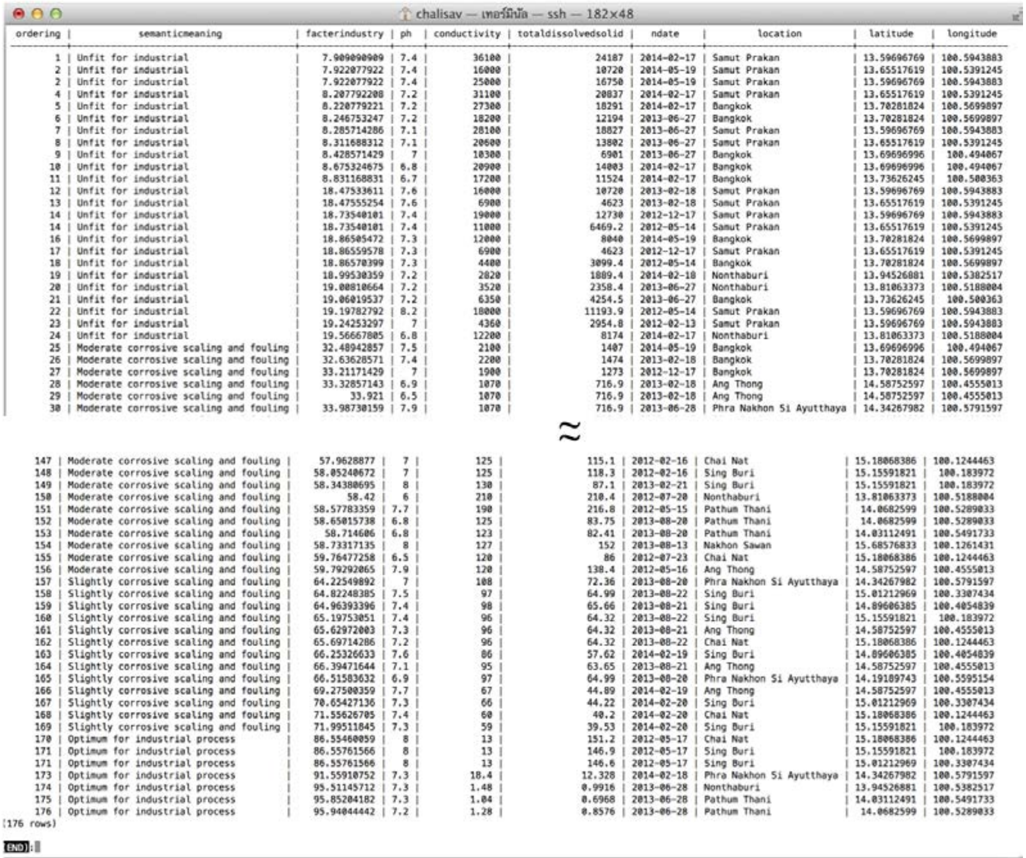
Fig. 6.64 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of fish (Query: fish, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Abundant for fish, Optimum for fish and shrimp, Bacteria and plankton being disappear, Hazard for fish and salmon dying, and All fish extinction)).



ordering	semanticmeaning	facterindustry	ph	conductivity	totaldissolvedsolid	ndate	location	latitude	longitude
1	Unfit for industrial	7.909090909	7.4	36100	24187	2014-02-17	Samut Prakan	13.59696769	100.5943883
2	Unfit for industrial	7.922077922	7.4	16000	10720	2014-05-19	Samut Prakan	13.65517619	100.5391245
2	Unfit for industrial	7.922077922	7.4	25000	16750	2014-05-19	Samut Prakan	13.59696769	100.5943883
4	Unfit for industrial	8.207792208	7.2	31100	20837	2014-02-17	Samut Prakan	13.65517619	100.5391245
5	Unfit for industrial	8.220779221	7.2	27300	18291	2014-02-17	Bangkok	13.70281824	100.5699897
6	Unfit for industrial	8.246753247	7.2	18200	12194	2013-06-27	Bangkok	13.70281824	100.5699897
7	Unfit for industrial	8.285714286	7.1	28100	18827	2013-06-27	Samut Prakan	13.59696769	100.5943883
8	Unfit for industrial	8.311688312	7.1	20600	13802	2013-06-27	Samut Prakan	13.65517619	100.5391245
9	Unfit for industrial	8.428571429	7	10300	6901	2013-06-27	Bangkok	13.69696996	100.494067
10	Unfit for industrial	8.675324675	6.8	20900	14003	2014-02-17	Bangkok	13.69696996	100.494067
11	Unfit for industrial	8.831168831	6.7	17200	11524	2014-02-17	Bangkok	13.73626245	100.500363
12	Unfit for industrial	18.47533611	7.6	16000	10720	2013-02-18	Samut Prakan	13.59696769	100.5943883
13	Unfit for industrial	18.47555254	7.6	6900	4623	2013-02-18	Samut Prakan	13.65517619	100.5391245
14	Unfit for industrial	18.73540101	7.4	19000	12730	2012-12-17	Samut Prakan	13.59696769	100.5943883
14	Unfit for industrial	18.73540101	7.4	11000	6469.2	2012-05-14	Samut Prakan	13.65517619	100.5391245
16	Unfit for industrial	18.86505472	7.3	12000	8040	2014-05-19	Bangkok	13.70281824	100.5699897
17	Unfit for industrial	18.86559578	7.3	6900	4623	2012-12-17	Samut Prakan	13.65517619	100.5391245
18	Unfit for industrial	18.86570399	7.3	4400	3099.4	2012-05-14	Bangkok	13.70281824	100.5699897
19	Unfit for industrial	18.99530359	7.2	2820	1889.4	2014-02-18	Nonthaburi	13.94526881	100.5382517
20	Unfit for industrial	19.00810664	7.2	3520	2358.4	2013-06-27	Nonthaburi	13.81063373	100.5188004
21	Unfit for industrial	19.06019537	7.2	6350	4254.5	2013-06-27	Bangkok	13.73626245	100.500363
22	Unfit for industrial	19.19782792	8.2	18000	11193.9	2012-05-14	Samut Prakan	13.59696769	100.5943883
23	Unfit for industrial	19.24253297	7	4360	2954.8	2012-02-13	Samut Prakan	13.59696769	100.5943883
24	Unfit for industrial	19.56667805	6.8	12200	8174	2014-02-17	Nonthaburi	13.81063373	100.5188004
25	Moderate corrosive scaling and fouling	32.48942857	7.5	2100	1407	2014-05-19	Bangkok	13.69696996	100.494067
26	Moderate corrosive scaling and fouling	32.63628571	7.4	2200	1474	2013-02-18	Bangkok	13.70281824	100.5699897
27	Moderate corrosive scaling and fouling	33.21171429	7	1900	1273	2012-12-17	Bangkok	13.70281824	100.5699897
28	Moderate corrosive scaling and fouling	33.32857143	6.9	1070	716.9	2013-02-18	Ang Thong	14.58752597	100.4555013
29	Moderate corrosive scaling and fouling	33.921	6.5	1070	716.9	2013-02-18	Ang Thong	14.58752597	100.4555013
30	Moderate corrosive scaling and fouling	33.98730159	7.9	1070	716.9	2013-06-28	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597

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147	Moderate corrosive scaling and fouling	57.9628877	7	125	115.1	2012-02-16	Chai Nat	15.18068386	100.1244463
148	Moderate corrosive scaling and fouling	58.05240672	7	125	118.3	2012-02-16	Sing Buri	15.15591821	100.183972
149	Moderate corrosive scaling and fouling	58.34380695	8	130	87.1	2013-02-21	Sing Buri	15.15591821	100.183972
150	Moderate corrosive scaling and fouling	58.42	6	210	210.4	2012-07-20	Nonthaburi	13.81063373	100.5188004
151	Moderate corrosive scaling and fouling	58.57783359	7.7	190	216.8	2012-05-15	Pathum Thani	14.0682599	100.5289033
152	Moderate corrosive scaling and fouling	58.65015738	6.8	125	83.75	2013-08-20	Pathum Thani	14.0682599	100.5289033
153	Moderate corrosive scaling and fouling	58.714606	6.8	123	82.41	2013-08-20	Pathum Thani	14.03112491	100.5491733
154	Moderate corrosive scaling and fouling	58.73317135	8	127	152	2013-08-13	Nakhon Sawan	15.68576833	100.1261431
155	Moderate corrosive scaling and fouling	59.76477258	6.5	120	86	2012-07-23	Chai Nat	15.18068386	100.1244463
156	Moderate corrosive scaling and fouling	59.79292065	7.9	120	138.4	2012-05-16	Ang Thong	14.58752597	100.4555013
157	Slightly corrosive scaling and fouling	64.22549892	7	108	72.36	2013-08-20	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
158	Slightly corrosive scaling and fouling	64.82248385	7.5	97	64.99	2013-08-22	Sing Buri	15.01212969	100.3307434
159	Slightly corrosive scaling and fouling	64.96393396	7.4	98	65.66	2013-08-21	Sing Buri	14.89606385	100.4054839
160	Slightly corrosive scaling and fouling	65.19753051	7.4	96	64.32	2013-08-22	Sing Buri	15.15591821	100.183972
161	Slightly corrosive scaling and fouling	65.62972003	7.3	96	64.32	2013-08-21	Ang Thong	14.58752597	100.4555013
162	Slightly corrosive scaling and fouling	65.69714286	7.2	96	64.32	2013-08-22	Chai Nat	15.18068386	100.1244463
163	Slightly corrosive scaling and fouling	66.25326633	7.6	86	57.62	2014-02-19	Sing Buri	14.89606385	100.4054839
164	Slightly corrosive scaling and fouling	66.39471644	7.1	95	63.65	2013-08-21	Ang Thong	14.58752597	100.4555013
165	Slightly corrosive scaling and fouling	66.51583632	6.9	97	64.99	2013-08-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
166	Slightly corrosive scaling and fouling	69.27500359	7.7	67	44.89	2014-02-19	Ang Thong	14.58752597	100.4555013
167	Slightly corrosive scaling and fouling	70.65427136	7.3	66	44.22	2014-02-20	Sing Buri	15.01212969	100.3307434
168	Slightly corrosive scaling and fouling	71.55626705	7.4	60	40.2	2014-02-20	Chai Nat	15.18068386	100.1244463
169	Slightly corrosive scaling and fouling	71.99511845	7.3	59	39.53	2014-02-20	Sing Buri	15.15591821	100.183972
170	Optimum for industrial process	86.55460059	8	13	151.2	2012-05-17	Chai Nat	15.18068386	100.1244463
171	Optimum for industrial process	86.55761566	8	13	146.9	2012-05-17	Sing Buri	15.15591821	100.183972
171	Optimum for industrial process	86.55761566	8	13	146.6	2012-05-17	Sing Buri	15.01212969	100.3307434
173	Optimum for industrial process	91.55910752	7.3	18.4	12.328	2014-02-18	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
174	Optimum for industrial process	95.51145712	7.3	1.48	0.9916	2013-06-28	Nonthaburi	13.94526881	100.5382517
175	Optimum for industrial process	95.85204182	7.3	1.04	0.6968	2013-06-28	Pathum Thani	14.03112491	100.5491733
176	Optimum for industrial process	95.94044442	7.2	1.28	0.8576	2013-06-28	Pathum Thani	14.0682599	100.5289033

(176 rows)

(END):

Fig. 6.65 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of industry (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).

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ordering	semanticmeaning	facterirrigation	conductivity	totaldissolvedsolid	salinity	ndate	location	latitude	longitude
1	Hazard for irragation	1.221374046	20900	14003	12.6	2014-02-17	Bangkok	13.69696996	100.494067
2	Hazard for irragation	2.13740458	18200	12194	10.8	2013-06-27	Bangkok	13.70281824	100.5699897
3	Hazard for irragation	2.442748092	17200	11524	10.2	2014-02-17	Bangkok	13.73626245	100.500363
4	Hazard for irragation	3.053435115	16000	10720	9	2014-05-19	Samut Prakan	13.65517619	100.5391245
5	Hazard for irragation	3.562340967	16000	10720	8	2013-02-18	Samut Prakan	13.59696769	100.5943883
6	Hazard for irragation	5.694504472	12200	8174	6.8	2014-02-17	Nonthaburi	13.81063373	100.5188004
7	Hazard for irragation	5.704376012	12000	8040	7	2014-05-19	Bangkok	13.70281824	100.5699897
8	Hazard for irragation	6.463104326	20600	13802	2.3	2013-06-27	Samut Prakan	13.65517619	100.5391245
9	Hazard for irragation	7.315001655	10300	6901	5.7	2013-06-27	Bangkok	13.69696996	100.494067
10	Hazard for irragation	10.83333333	19000	12730	1.2	2012-12-17	Samut Prakan	13.59696769	100.5943883
11	Hazard for irragation	11.54761905	18000	11193.9	1	2012-05-14	Samut Prakan	13.59696769	100.5943883
12	Hazard for irragation	12.20860224	6900	4623	4	2013-02-18	Samut Prakan	13.65517619	100.5391245
13	Hazard for irragation	16.28590176	11000	6469.2	0.6	2012-05-14	Samut Prakan	13.65517619	100.5391245
14	Hazard for irragation	17.21951183	6350	4254.5	1.71	2013-06-27	Bangkok	13.73626245	100.500363
15	Hazard for irragation	18.73428336	2820	1889.4	1.3	2014-02-18	Nonthaburi	13.94526881	100.5382517
16	Hazard for irragation	21.12744379	6900	4623	0.4	2012-12-17	Samut Prakan	13.65517619	100.5391245
17	Hazard for irragation	21.22051646	3520	2358.4	1.7	2013-06-27	Nonthaburi	13.81063373	100.5188004
18	Hazard for irragation	21.92126814	2100	1407	0.1	2014-05-19	Bangkok	13.69696996	100.494067
19	Hazard for irragation	22.08905737	2200	1474	1	2013-02-18	Bangkok	13.70281824	100.5699897
20	Hazard for irragation	23.4260092	4360	2954.8	0.26	2012-02-13	Samut Prakan	13.59696769	100.5943883
21	Hazard for irragation	23.57861468	4400	3099.4	0.2	2012-05-14	Bangkok	13.70281824	100.5699897
22	Hazard for irragation	25.35409912	1900	1273	0.1	2012-12-17	Bangkok	13.70281824	100.5699897
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2013-06-29	Ang Thong	14.58752597	100.4555013
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2012-12-19	Sing Buri	14.89606385	100.4054839
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2012-12-19	Sing Buri	15.01212969	100.3307434
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2012-12-20	Sing Buri	15.15591821	100.183972
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2012-12-20	Chai Nat	15.18068386	100.1244463
23	Hazard for irragation	25.5635089	1070	716.9	1.1	2013-06-29	Ang Thong	14.58752597	100.4555013
29	Hazard for irragation	26.79622214	1070	716.9	1.1	2013-02-18	Ang Thong	14.58752597	100.4555013
29	Hazard for irragation	26.79622214	1070	716.9	1.1	2013-02-18	Ang Thong	14.58752597	100.4555013
31	Hazard for irragation	27.24244048	930	623.1	0.4	2014-02-18	Pathum Thani	14.0682599	100.5289033
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140	Moderate hazard for irrigation	57.89078882	135	90.45	0	2013-06-30	Sing Buri	15.15591821	100.183972
142	Moderate hazard for irrigation	57.93333043	130	107.9	0	2012-02-16	Sing Buri	15.01212969	100.3307434
143	Moderate hazard for irrigation	57.9911722	133	89.11	0	2013-06-30	Chai Nat	15.18068386	100.1244463
144	Moderate hazard for irrigation	58.03653684	130	97.6	0	2012-07-23	Sing Buri	15.01212969	100.3307434
145	Moderate hazard for irrigation	58.04651332	125	118.3	0	2012-02-16	Sing Buri	15.15591821	100.183972
146	Moderate hazard for irrigation	58.06250182	120	138.4	0	2012-05-16	Ang Thong	14.58752597	100.4555013
147	Moderate hazard for irrigation	58.07857744	125	115.1	0	2012-02-16	Chai Nat	15.18068386	100.1244463
148	Moderate hazard for irrigation	58.14174726	130	87.1	0	2013-02-21	Sing Buri	15.15591821	100.183972
149	Moderate hazard for irrigation	58.3927057	125	83.75	0	2013-08-20	Pathum Thani	14.0682599	100.5289033
150	Moderate hazard for irrigation	58.49308908	123	82.41	0	2013-08-20	Pathum Thani	14.03112491	100.5491733
151	Moderate hazard for irrigation	58.58755192	120	86	0	2012-07-23	Chai Nat	15.18068386	100.1244463
152	Moderate hazard for irrigation	59.24596439	108	72.36	0	2013-08-20	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
153	Moderate hazard for irrigation	59.74788127	98	65.66	0	2013-08-21	Sing Buri	14.89606385	100.4054839
154	Moderate hazard for irrigation	59.79807296	97	64.99	0	2013-08-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
154	Moderate hazard for irrigation	59.79807296	97	64.99	0	2013-08-22	Sing Buri	15.01212969	100.3307434
156	Moderate hazard for irrigation	59.84826465	96	64.32	0	2013-08-22	Sing Buri	15.15591821	100.183972
156	Moderate hazard for irrigation	59.84826465	96	64.32	0	2013-08-21	Ang Thong	14.58752597	100.4555013
156	Moderate hazard for irrigation	59.84826465	96	64.32	0	2013-08-22	Chai Nat	15.18068386	100.1244463
159	Moderate hazard for irrigation	59.89845633	95	63.65	0	2013-08-21	Ang Thong	14.58752597	100.4555013
160	Moderate hazard for irrigation	60.35018152	86	57.62	0	2014-02-19	Sing Buri	14.89606385	100.4054839
161	Excellent for irrigation	79.59350392	67	44.89	0	2014-02-19	Ang Thong	14.58752597	100.4555013
162	Excellent for irrigation	79.69907351	66	44.22	0	2014-02-20	Sing Buri	15.01212969	100.3307434
163	Excellent for irrigation	80.33249107	60	40.2	0	2014-02-20	Chai Nat	15.18068386	100.1244463
164	Excellent for irrigation	80.43806066	59	39.53	0	2014-02-20	Sing Buri	15.15591821	100.183972
165	Excellent for irrigation	83.39058794	13	151.2	0	2012-05-17	Chai Nat	15.18068386	100.1244463
166	Excellent for irrigation	83.44803617	13	146.9	0	2012-05-17	Sing Buri	15.15591821	100.183972
167	Excellent for irrigation	83.45204418	13	146.6	0	2012-05-17	Sing Buri	15.01212969	100.3307434
168	Excellent for irrigation	84.72418615	18.4	12.328	0	2014-02-18	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
169	Excellent for irrigation	85.71042367	1.48	0.9916	0.06	2013-06-28	Nonthaburi	13.94526881	100.5382517
170	Excellent for irrigation	85.86487092	1.28	0.8576	0.05	2013-06-28	Pathum Thani	14.0682599	100.5289033
171	Excellent for irrigation	86.02354096	1.04	0.6968	0.04	2013-06-28	Pathum Thani	14.03112491	100.5491733

(171 rows)

(END):

Fig. 6.66 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of irrigation (Query: irrigation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 3 conditions: Excellent for irrigation, Moderate hazard for irrigation, and Hazard for irrigation)).

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ordering	semanticmeaning	factorrecreation	e_coli	coliform	ndate	location	latitude	longitude
1	Strongly risk of illness	57.23791067	92000	68000	2013-06-27	Samut Prakan	13.65517619	100.5391245
2	Strongly risk of illness	57.8875969	28000	132000	2013-08-13	Nakhon Sawan	15.68576833	100.1261431
3	Strongly risk of illness	59.28294574	54000	106000	2013-02-21	Chai Nat	15.18068386	100.1244463
4	Critical risk of illness	62.5092285	50000	40000	2014-05-19	Chai Nat	15.42268813	100.138766
5	Critical risk of illness	62.52307124	35000	57000	2013-02-18	Bangkok	13.70281824	100.5699897
6	Critical risk of illness	62.7057955	17000	75000	2014-05-19	Nonthaburi	13.81063373	100.5188004
6	Critical risk of illness	62.7057955	17000	75000	2012-07-20	Nonthaburi	13.81063373	100.5188004
8	Critical risk of illness	62.74640089	13000	79000	2013-08-19	Samut Prakan	13.59696769	100.5943883
9	Critical risk of illness	62.90513104	11000	79000	2012-07-08	Nakhon Sawan	15.68576833	100.1261431
10	Critical risk of illness	63.13999631	7900	152100	2012-05-14	Bangkok	13.69696996	100.494067
11	Critical risk of illness	64.11175711	7900	84100	2014-05-19	Bangkok	13.70281824	100.5699897
11	Critical risk of illness	64.11175711	7900	84100	2013-06-27	Bangkok	13.69696996	100.494067
13	Critical risk of illness	65.01522702	4700	155300	2012-07-20	Bangkok	13.70281824	100.5699897
14	Critical risk of illness	65.15319306	35000	19000	2014-05-19	Bangkok	13.73626245	100.500363
15	Critical risk of illness	65.22425249	28000	26000	2012-07-20	Samut Prakan	13.65517619	100.5391245
16	Critical risk of illness	65.33591731	17000	37000	2012-02-13	Bangkok	13.73626245	100.500363
17	Critical risk of illness	65.3765227	13000	41000	2013-08-19	Bangkok	13.73626245	100.500363
17	Critical risk of illness	65.3765227	13000	41000	2012-07-20	Bangkok	13.73626245	100.500363
19	Critical risk of illness	65.3968254	11000	43000	2013-06-27	Nonthaburi	13.81063373	100.5188004
20	Critical risk of illness	66.05297158	4000	88000	2012-07-20	Bangkok	13.69696996	100.494067
21	Critical risk of illness	66.57991879	24000	11000	2012-07-20	Samut Prakan	13.59696769	100.5943883
21	Critical risk of illness	66.57991879	24000	11000	2013-08-19	Samut Prakan	13.65517619	100.5391245
23	Critical risk of illness	66.65097822	17000	18000	2012-12-17	Bangkok	13.73626245	100.500363
23	Critical risk of illness	66.65097822	17000	18000	2014-02-17	Nonthaburi	13.81063373	100.5188004
23	Critical risk of illness	66.65097822	17000	18000	2013-02-19	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
26	Critical risk of illness	66.69158361	13000	22000	2013-06-27	Samut Prakan	13.59696769	100.5943883
27	Critical risk of illness	66.7118863	11000	24000	2013-08-19	Bangkok	13.69696996	100.494067
28	Critical risk of illness	66.77325581	1700	158300	2012-07-23	Sing Buri	15.01212969	100.3307434
29	Critical risk of illness	66.99704688	17000	13000	2014-05-19	Nakhon Sawan	15.68576833	100.1261431
30	Critical risk of illness	67.10535778	14000	7000	2012-02-13	Bangkok	13.69696996	100.494067

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152	Moderately risk of illness	82.3530205	780	920	2012-12-19	Ang Thong	14.58752597	100.4555013
153	Moderately risk of illness	83.18079153	450	2850	2012-02-15	Sing Buri	14.89606385	100.4054839
154	Moderately risk of illness	83.51368662	200	4700	2012-02-15	Ang Thong	14.58752597	100.4555013
154	Moderately risk of illness	83.51368662	200	4700	2013-02-19	Nonthaburi	13.94526881	100.5382517
156	Moderately risk of illness	83.71763754	400	2600	2012-11-05	Chai Nat	15.42268813	100.138766
157	Moderately risk of illness	83.93928668	450	1850	2012-07-21	Pathum Thani	14.03112491	100.5491733
158	Moderately risk of illness	84.69778182	450	850	2014-02-18	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
159	Moderately risk of illness	84.72727886	200	3100	2013-06-28	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
159	Moderately risk of illness	84.72727886	200	3100	2014-05-22	Sing Buri	15.01212969	100.3307434
159	Moderately risk of illness	84.72727886	200	3100	2012-07-22	Ang Thong	14.58752597	100.4555013
162	Moderately risk of illness	84.78994741	610	4290	2012-05-15	Pathum Thani	14.03112491	100.5491733
163	Moderately risk of illness	85.15877832	400	700	2012-05-16	Ang Thong	14.58752597	100.4555013
163	Moderately risk of illness	85.15877832	400	700	2013-06-30	Chai Nat	15.18068386	100.1244463
165	Moderately risk of illness	85.485774	200	2100	2012-12-18	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
165	Moderately risk of illness	85.485774	200	2100	2012-05-17	Chai Nat	15.18068386	100.1244463
167	Moderately risk of illness	85.56162352	200	2000	2012-02-16	Sing Buri	15.01212969	100.3307434
167	Moderately risk of illness	85.56162352	200	2000	2014-02-20	Sing Buri	15.15591821	100.183972
167	Moderately risk of illness	85.56162352	200	2000	2013-08-22	Sing Buri	15.01212969	100.3307434
170	Moderately risk of illness	86.24426915	200	1100	2012-07-07	Nakhon Sawan	15.54754128	100.1170992
171	Moderately risk of illness	86.46312028	680	2020	2012-12-18	Pathum Thani	14.03112491	100.5491733
172	Moderately risk of illness	86.63868662	200	580	2014-05-22	Chai Nat	15.18068386	100.1244463
173	Moderately risk of illness	86.71453614	200	480	2014-05-20	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
173	Moderately risk of illness	86.71453614	200	480	2014-05-22	Sing Buri	15.15591821	100.183972
175	Moderately risk of illness	86.82072546	200	340	2014-05-21	Ang Thong	14.58752597	100.4555013
176	Litter risk of illness	87.84722222	200	250	2013-02-21	Sing Buri	15.15591821	100.183972
177	Litter risk of illness	88.42592593	200	200	2014-02-20	Chai Nat	15.18068386	100.1244463
178	Litter risk of illness	90.69444444	180	20	2012-12-20	Sing Buri	15.15591821	100.183972
179	Litter risk of illness	90.74074074	200	0	2014-02-17	Samut Prakan	13.59696769	100.5943883

(179 rows)

(END):

Fig. 6.67 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of recreation (Query: recreation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Little risk of illness, Moderately risk of illness, Critical risk of illness, Strongly risk of illness, and Excessively risk of illness)).

6.6 The integration between parameter relatedness weighting method and rHMEI in an industry context

A multi-dimensional space idea and semantic computing of water-quality analysis are should be implemented into the various parameter of physical, chemical and heavy metal features. Due to different types of dose response function of physical and chemical features (step function) and heavy metal feature (segmented function), the aggregated method can not be able to combine together. Thus, this approach is divided into 2 methods as below:

- Parameter relatedness weighting method of physical and chemical features.
- rHMEI of heavy metal features.

The significant parameter for industry context is (1) pH, which harmful for equipment (corrosive, scaling, and deposits in equipment), (2) Conductivity, which could damaging equipment (encrusts and/or corrodes surfaces of metal) and effects to interrupt chemical processes, and impairment of product quality, (3) total dissolved solid, which damage to process by indirectly interfacing with the proper function of several industrial processes causing damage and chronic corrosion, scaling, and fouling of equipment, and dietary increased intake of toxic metals leached from water pipes, and (4) heavy metal, which damage in precipitation of metal compounds, interference in processes, impairment of product quality, accumulation in product of food and drinking industry, and cause blockages in pipe and nozzles,

By using the parameter relatedness weightless method and rHMEI, this system can provide the semantic meaning includeing an effect on industrial equipment and process, by applying semantic computing. In the same data set, two methods are applyies. First, applying the parameter relatedness weightless method to analyze the physical and chemical features and interpreting to the meaningful word which are including effect on the industrial equipment and process as (1) optimum of industrial process, (2) slightly corrosive scaling and fouling, (3) moderate corrosive scaling and fouling, (4) highly corrosive scaling and fouling, and (5) unfit for industrial process. While rHMEI method uses for analyzing the heavy metal features which can be provided the meaningful word results as a (1) optimum of industrial process, and (2) unfit, highly corrosive, scaling and fouling for industrial process. For sharply water-quality analysis, this system combines the results from 2 methods and provides the sharply meaningful word of water-quality and suggesting the solution to users. The interpretation of the integration between parameter relatedness weightless method and rHMEI is shown as Table 6.5 -6.7

Where

A is optimum of industrial process,
B is slightly corrosive scaling and fouling,
C is moderate corrosive scaling and fouling,
D is highly corrosive scaling and fouling,
E is unfit for industrial process,
I is optimum of industrial process,
II is unfit, highly corrosive, scaling and fouling for industrial process

Table 6.5 The interpretation of the integration between parameter relatedness weighting method and rHMEI.

Condition	Integration meaning in industry context	An effect in food and drinking industry	Suggested solution to user
A-I	Absolutely appropriate to use	Absolutely appropriate to use	None
A-II	Appropriate to use (treatment is needed)	Appropriate to use and toxicity from heavy metal (treatment is needed) (an effect in acute-choric cancer, brain function, kidneys, lung, nausea vomiting, blood, and destroy the development of organism)	Heavy metals treatment process are needed
B-I	Appropriate to use (treatment is needed)	Appropriate to use (treatment is needed)	Slightly treatment process for physical and chemical parameters are needed
B-II	Appropriate to use(but treatment is needed)	Appropriate to use and toxicity from heavy metal (treatment is needed) (an effect in acute-choric cancer, brain function, kidneys, lung, nausea vomiting, blood, and destroy	Slightly treatment process for physical, chemical, and heavy metal parameters are needed

Table 6.6 The interpretation of the integration between parameter relatedness weighting method and rHMEI (*Cont*.).

Condition	Integration meaning in industry context	An effect in food and drinking industry	Suggested solution to user
		the development of organism)	
C-I	Moderate appropriate to use (treatment is needed)	Moderate appropriate to use (treatment is needed)	Moderate treatment process for physical and chemical parameters are needed
C-II	Moderate appropriate to use (treatment is needed)	Moderate inappropriate to use and toxicity from heavy metal (treatment is needed) (an effect in acute-choric cancer, brain function, kidneys, lung, nausea vomiting, blood, and destroy the development of organism)	Moderate treatment process for physical, chemical, and heavy metal parameters are needed
D-I	Slightly inappropriate to use (treatment is needed)	Slightly inappropriate to use (treatment is needed)	Highly treatment process for physical and chemical parameters are needed
D-II	Slightly inappropriate to use (treatment is needed)	Slightly inappropriate to use and toxicity from heavy metal (treatment is needed) (an effect in acute-choric cancer, brain function, kidneys, lung, nausea vomiting, blood, and destroy the development of organism)	Highly treatment process for physical, chemical, and heavy metal parameters are needed
E-I	Inappropriate to use (treatment is needed)	Inappropriate to use (treatment is needed)	Strongly treatment process for physical and chemical parameters are needed

Table 6.7 The interpretation of the integration between parameter relatedness weightling method and rHMEI (*Cont*.).

Condition	Integration meaning in industry context	An effect in food and drinking industry	Suggested solution to user
E-II	Inappropriate to use (treatment is needed)	Inappropriate to use (treatment is needed)	Strongly treatment process for physical, chemical, and heavy metal parameters are needed

Chapter 7

Evaluation

This chapter describes the evaluation method for the multi-dimensional semantic space of the river water-quality analysis system with an accuracy evaluation calculation by specialists, considering the accuracy calculation which is used for comparing other standards [34, 40, 33, 41] for comparison of the method in the thesis and other international research studies.

7.1 An accuracy calculation

This research uses raw data from 100 data sets from different places with diverse characteristics of water. The data were acquired in Thailand, Laos, Japan, Indonesia, and Finland for checking the accuracy from the real situation. The formula for calculation is Eq. 7.1

$$Accuracy = \frac{|Q_t - Q_e|}{Q_t} * 100 \tag{7.1}$$

when

Q_t is a total of raw data set

Q_e is a total of error results

The comparison result with an accuracy assessment from river water-quality standards from another research study shows the accuracy of our proposed method. It is acceptable in diverse-study areas because it provides either equal or higher precision with the international standard criteria (FAO, WHO2006, Texas). The comparison of the accuracy assessment results from water-quality standards of the river with other research studies is shown in Figure 7.1.

The result in comparison with an accuracy assessment from the river water-quality standard of river (aquatic life) with other research study shows the accuracy of the proposed method. It is acceptable in diverse-study areas positively because it provides either equal or higher precision with the international standard criteria (CCME, Thai (PCD)). The comparison of accuracy assessment results from water-quality standard of the river (aquatic life) with other research study is shown in Figure 7.2.

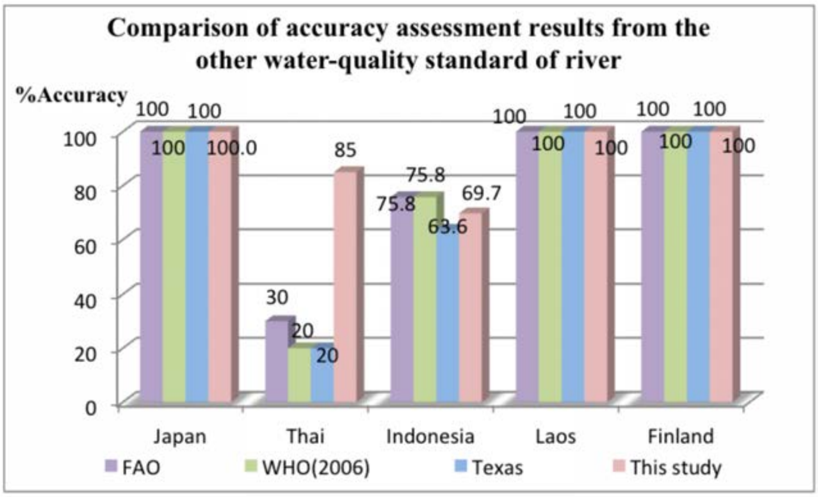

Fig. 7.1 The comparison of accuracy assessment results from water-quality standard of river.

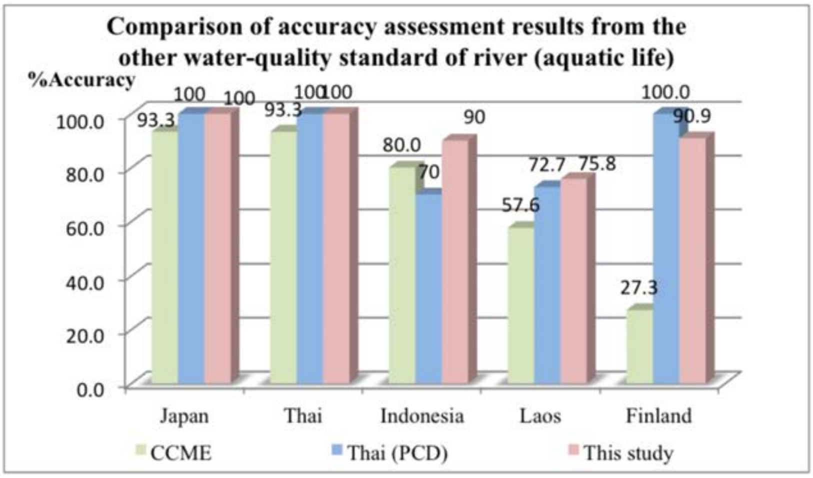

Fig. 7.2 The comparison of accuracy assessment results from water-quality standard of river (aquatic life).

7.2 The comparison with the other research

In this subsection, the proposed method and criteria in this study are compared with other researches on water-quality indicators for determining the quality of water resources. The evaluation consists of two parts as below:

- The comparison of physical and chemical features.
- The comparison of heavy metal features.

The comparison with other related researches on water-quality of physical and chemical features and heavy metal features is shown in Table 7.1, 7.2 and 7.3.

There are several types of research, which apply water-quality index to determining the quality of water resources and defining the related parameters from 3 - 18 parameters [20, 75 - 83] and heavy metal index from 4 - 8 parameters [71, 84 - 87], based on analyzed purpose in standard of ISO 5667-6 [42]. The purpose of this study is realizing water-quality analysis in different contexts in dynamic sub-space selection according to contexts based on dimensional idea and semantic computing in a Mathematic Model of Meaning concept (MMM). One of the original ideas in semantic computing in a MMM is sub-space selection according to contexts, which is promising approach for interpreting water resources' situation in dynamic contexts. Thus, in this study, the number of features are not related to the accuracy of the analysis. Rather, the selection of specific feature which used for defining sub-space selection in context is an important criteria for acquiring the similar meaning from measurement data.

The most important difference between this study and other researches is the number of contexts in analysis, which is a dynamic changing context, meaningful words of the interpretation results (see in Chapter 3 in section 3.5.3.4-1), and low-to-high toxicity features included in semantic computing.

Where

Cond is conductivity (the concentration of this parameter is reported in μS),
DO is Dissolved oxygen (the concentration of this parameter is reported in mg/L),
pH is potential of hydrogen ion (the concentration of this parameter is reported in standard unit),
Sali is salinity (the concentration of this parameter is reported in ppt),
Temp is temperature (the concentration of this parameter is reported in degree C),
TP is total phosphate (the concentration of this parameter is reported in mg/L),
NO_3 is nitrate (the concentration of this parameter is reported in mg/L),

NO_2 is nitrite (the concentration of this parameter is reported in mg/L),
Turb is turbidity (the concentration of this parameter is reported in NTU),
TS is total solid (the concentration of this parameter is reported in mg/L),
TDS is total dissolved solid (the concentration of this parameter is reported in mg/L),
FCB is Fecal Coliform Bacteria (the concentration of this parameter is reported in CFU/100 ml),
TCB is Total Coliform Bacteria (the concentration of this parameter is reported in MPN/100 ml),
E coli is Escherichia coli (the concentration of this parameter is reported in CFU/100 ml),
Entero is Enterococci Bacteria (the concentration of this parameter is reported in CFU/100 ml),
CB is Coliform Bacteria (the concentration of this parameter is reported in MPN/100 ml),
SS is suspended solid (the concentration of this parameter is reported in mg/L),
BOD is biological oxygen demand (the concentration of this parameter is reported in mg/L),
COD is chemical oxygen demand (the concentration of this parameter is reported in mg/L),
NH_3 is ammonia (the concentration of this parameter is reported in mg/L),
Alk is alkalinity (the concentration of this parameter is reported in mg//L),
Har is hardness (the concentration of this parameter is reported in mg/L as $CaCO_3$),
Ca is calcium (the concentration of this parameter is reported in mg/L),
Mg is manganese (the concentration of this parameter is reported in mg/L),
Cl is choride (the concentration of this parameter is reported in mg/L),
SO_4 is sulfate (the concentration of this parameter is reported in mg/L),
PO_4 is phosphate(the concentration of this parameter is reported in mg/L)

Table 7.1 The comparison with other related researches on water-quality index.

Existing research	Index	Parameter	Type of parameter	Number of analysis context	Number of class in context
K. Charuvan, et al. (2012) [75]	NSF-WQI	8	DO, pH, Temp, TP, NO_3, Turb, TS, and FCB	1	5
K. Charuvan, et al. (2012) [75]	DOE-WQI	8	DO, pH, Temp, TP, NO_3, Turb, TS, and FCB	1	3
A. A. Bordalo, et al. (2001) [20]	PCD-WQI	9	Temp, DO, Turb, SS, pH, NH3, FC, BOD, and COD	1	5
N. Singkran, et al. (2010) [76]	PCD-WQI	6	DO, BOD, NO_3, TP, FCB, and SS	1	4
S. Choo-In, et al. (2015) [77]	PCD-WQI	5	DO, BOD, NH_3, FCB, and TCB	1	4
K. Yogendra and E. T. Puttaiah (2008) [78]	WQI	13	pH, Cond, TDS, Alk, har, TSS, Ca, Mg, Cl, NO_3, SO_4, DO, and BOD	1	5
P. R. Kannel, et al. (2007) [79]	WQI	18	Temp, pH, DO, Cond, TDS, Ca, Mg, SO_4, Cl, PO_4, TP, NH_3, NO_3, NO_2, BOD, COD, har, and TSS	1	2

Table 7.2 The comparison with other related researches on water-quality index (*Cont.*)

Existing research	Index	Parameter	Type of parameter	Number of analysis context	Number of class in context
P. R. Kannel, et al. (2007) [79]	WQI-min	5	Temp, pH, DO, Cond, and TSS	1	2
P. R. Kannel, et al. (2007) [79]	WQI-DO	1	DO	1	2
P. Samantray, et al. (2009) [80]	WQI	4	pH, DO, BOD, and FCB	1	5
C. Prakirake, et al. (2012) [81]	WSI	12	DO, pH, NO_3, TDS, FCB, Fe, Color, BOD, Mn, NH_3, har, and PO_4	1	5
T. Netpae (2014) [82]	WQI	5	DO, BOD, NO_3, CB, and FCB	1	4
B. N.Lohani and and G. Todino (2012) [83]	WQI	13	pH, Temp, DO, turb, SS, Cl, NO3, NO2, TN, PO4, BOD, Cond, and CB	1	4
This study	Increasing index	9	pH, DO, Cond, TDS, Turb, Sal, E coli, Entero, and CB	7	3-8
	Decreasing index	9	pH, DO, Cond, TDS, Turb, Sal, E coli, Entero, and CB	7	3-8

Table 7.3 The comparison with other related researches on Metal index.

Existing research	Index	Parameter	Type of parameter	Number of analysis context	Number of class in context
E. G. Ameh, and F. A. Akpah (2011) [84]	HPI	7	Mg, Pb, Zn, Ni, Cu, Cd, and Fe	1	1
M. E. Goher, et al. (2014) [70]	MI	8	Al, Cd, Cu, Fe, Mn, Ni, Pb, and Zn	1	1
S. Sobhanardakani, et al. (2016) [85]	HEI	5	As, Zn, Pb, Cd, and Cu	1	1
M. Kumar, et al. (2012) [86]	HPI	6	Fe, Zn, Cu, Pb, Cd, and Mn	1	1
A. Satar, et al. (2017) [87]	HPI	7	Fe, Mn, Zn, Ni, Cu, Pb, and Cd	1	1
P. Amirhossein. et al. (2015) [71]	PLI	8	Fe, Cu, Zn, Cr, Ni, Pb, Cd, and V	1	1
This study	rHMEI	9	As, Cd, Cr, Cu, Fe, Pb, Hg, Ni, and Zn	5	2

Where
Al is aluminum (the concentration of this parameter is reported in mg/L),
As is arsenic (the concentration of this parameter is reported in μg/L),
Cd is cadmium (the concentration of this parameter is reported in μg/L),
Cr is chromium (the concentration of this parameter is reported in μg/L),
Cu is copper (the concentration of this parameter is reported in mg/L),
Mn is manganese (the concentration of this parameter is reported in mg/L),
Mg is magnesium (the concentration of this parameter is reported in mg/L),
Fe is iron (the concentration of this parameter is reported in mg/L),
Pb is lead (the concentration of this parameter is reported in mg/L),
Hg is mercury (the concentration of this parameter is reported in μg/L),
Ni is nickel (the concentration of this parameter is reported in μg/L),
Zn is zinc (the concentration of this parameter is reported in mg/L),
V is vanadium (the concentration of this parameter is reported in mg/L)

There are several implementations in previous water-quality analysis research which are studied in significant parts of the analysis results: (1) Local situation water-quality analysis and assessment results, which information is not provided to the public globally. (2) In spite of this, there are data collected from different areas which scholars use different criteria and frameworks to analyze. (3) The existing implementations cannot explain meanings widely and also are too complicated for the public to utilize. Consequently, the tool and processes to analyze system are realized to the limitation in water quality analysis significantly. This dissertation proposes an automatic system for water-quality analysis using several databases and different contexts and in dynamic sub-space selection contexts which are new environments for water-quality interpretation presenting an easier way to understand the information by transforming the sensor-value information to language information. In this dissertation, innovative correlations for a river water quality analysis system are presented as an automatic human-interpreting system by integrating the special knowledge of environmental engineering and semantic computing, which relies on the knowledge of professional, and the semantics calculated from the features for various environmental issues, especially the water-quality semantic space. The system in this dissertation is achieves the limitation of previous implementations by creating new aspect in river-water-quality system. The important points of created mathematic formulas in this study describes as below:

- Mathematic formula for the different types of dose response function
  All features in this study are not aggregated together but computed by

different mathematic formula because the concentration of the physical and chemical features is represented in a step function, while the concentration of the heavy metal feature is represented in a segmented function. The dose response curve of damage for the physical and chemical features is shown in Figure 7.3, and the dose response curve of damage for the heavy metal features is shown in Figure 7.4

- Mathematic formula for the different unit of features
  One of the limitations of existing method is that different unit parameters are not normalized in the same scale, which causes inaccurate result [7]. The collected water quality features in this study are not in a same unit. In the case, variable features with different units and dimension are normalized and converted into sub-factor with a common scale (0-100). After the conversion, the weight is assigned to the sub-factor, and the factor's total value F is calculated.

- Mathematic formula for the physical and chemical features
  This study defines mathematic formula for the sub-factor of physical and chemical features by two types of indicator. One is a bigger indicator. This is used for a sub-factor, in which a bigger value represents better quality of water such as dissolved oxygen (DO). The other is a smaller indicator. This is used for the other sub-factors, in which a smaller value represents better quality of water such as turbidity, conductivity, salinity, and total dissolved solid (TDS).

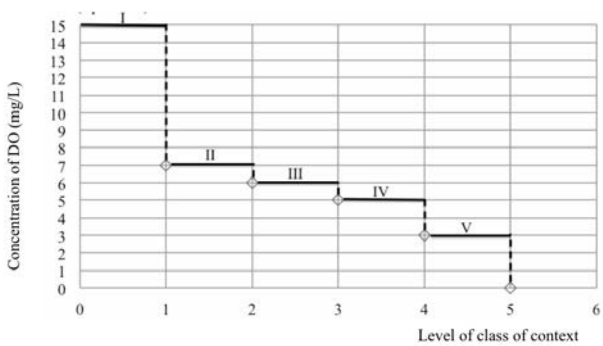

Fig. 7.3 The dose response curve of the physical and chemical parameters as a step function.

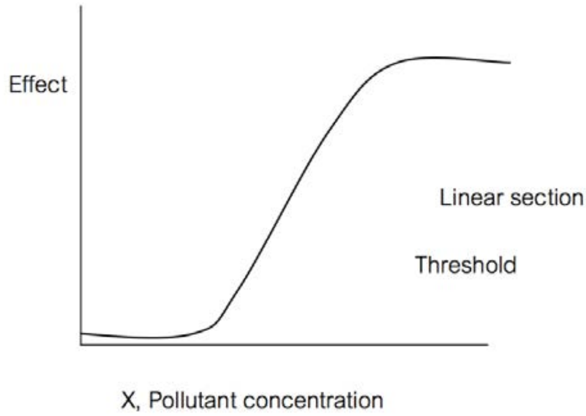

Fig. 7.4 The dose response curve of heavy metal parameters as a segmented function.

7.3 Water-quality Questionnaire and Feedback (Mechanism to reflect/feedback specialists' knowledge)

This questionnaire and feedback are the mechanisms to focus and reflect on the specialists' knowledge. This new information forms the basis for the specific part of the semantic computing based on the specialists' knowledge. From this mechanism, the specialists' knowledge is reflected in the system in the parts relating to the water-quality criteria for deep analysis and the water quality interpretation using semantic computing in MMM [12], which are analyzed in depth as the semantic meaningful words.

In addition to the evaluation and feedback from the specialists, the consideration in the reflection depends on the specialists' knowledge as input into the system. This section uses the water-quality questionnaire and feedback from the specialists in the field of water-quality analysis as the tools for reflecting the specialists' knowledge in the system. The evaluation and feedback consist of 2 parts as follows:

- Feedback of water-quality criteria and classification class in each context
- Feedback of suggestion for improvement system

During the evaluation and feedback processes, two types of specialists in the water-quality analysis field were included: (1) academics, and (2) Government and private institute sector specialists. The details of the specialist are described below

Academic part

1.1 The specialist's position (7 persons):

- Professor (2 persons)
- Associate Professor (2 persons)
- Lecturer (2 persons)
- Postdoctoral (1 person)

1.2 The specialist's field:

- Water and Wastewater treatment (3 persons)
- Environmental Engineering (3 persons)
- Natural treatment Engineering (1 person)

1.3 Name of organization/institute:

- University A (2 persons)
- University B (1 person)
- University C (2 persons)
- University D (1 person)
- University E (1 person)

Government and private Institute sector

1.1 The specialist's position (8 persons):

- Environmental scientist (4 persons)
- Environmental engineering (3 persons)
- Sanitary technical office (1 person)

1.2 The specialist's field:

- Air quality, noise level, vibration level, and water-quality monitoring (1 person)
- Environmental impact assessment and analysis in water pollution (1 person)

- Environmental impact assessment and analysis in water source (2 persons)
- Environmental impact assessment in water, air, and waste pollution (1 person)
- Water quality Analysis (1 person)
- Health Risk Assessment of air and Water pollution (1 person)
- Water pollution control management (1 person)

1.3 Name of organization/institute:

- Private Institute A (1 person)
- Private Institute B (1 person)
- Private Institute C (1 person)
- Government Institute A (1 person)
- Government Institute B (1 person)
- Government Institute C (1 person)
- Government Institute D (1 person)
- Government Institute E (1 person)

Table 7.4 The information of specialists

Sector	ID	Position	Institute	Specialist's field	Year of experience
Academic part	A1	Professor	University A	Environmental engineering	35
	A2	Professor, Director	University B	Wastewater treatment	28
	A3	Associate Professor	University C	Natural treatment Engineering	28

Table 7.5 The information of specialists (*Cont.*)

Sector	ID	Position	Institute	Specialist's field	Year of experience
	A4		University A	Water and Wastewater treatment	25
	A5	Lecture	University C	Water and Wastewater treatment	25
	A6		University D	Water and Wastewater treatment	12
	A7	Postdoctoral	University E	Environmental engineering	9
Government and private Institute part	B1	Sanitary Technical officer	Government Institute A	Water Quality Analysis	11
	B2	Environmental scientist	Government Institute B	Water pollution control management	7
	B3	Environmental scientist	Private Institute A	Air quality, noise level, vibration level, and water-quality monitoring	7
	B4		Private Institute B	Environmental impact assessment in water pollution	
	B5		Private Institute C	Health Risk Assessment of air and water pollution	5
	B6	Environmental engineering	Government Institute C	Environmental impact assessment and analysis in water pollution	8

Table 7.6 The information of specialists (*Cont*.)

Sector	ID	Position	Institute	Specialist's field	Year of experience
	B7		Government Institute D	Environmental impact assessment and analysis in water source	7
	B8		Government Institute E	Environmental impact assessment and analysis in water source	6

7.3.1 The Summary of the Questionnaire and Feedback

Physical, chemical, and biological parameters

Context of Agriculture

This subsection summarized the results from the specialists using the answers in the context of agriculture. The feedback results are shown in Figure 7.5 and are described in detail below

1) Question and Condition: Conductivity is less than 29 μS/cm, total dissolved solid is less than 130 mg/L, and salinity is less than 0.13 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of agriculture?

- Excellent for agriculture (A2, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
- Hazardous for sensitive crop (A5)
- Hazardous for low tolerance crop (A1)
- Hazardous for high tolerance crop
- Satisfactory for livestock and poultry
- Hazard for Poultry
- Unfit for agriculture

- Suddenly toxic for agriculture

The reason, comment, and feedback: Salinity may be too high (A1). It contains low salinity (A2). There is not an answer using this information, there is not enough information to conclude that the water is appropriate for all agricultural activity. There should be other water indicators provided for consideration such as nutrients and metal ions (A3). The parameters given in the question are not sufficient to justify the answer, the parameters do not include heavy metal ions and pesticides (A4). It is in a good condition for crops (B3). Conductivity is very low (B4). The United States Salinity Laboratory (USSL, 1954) has classified a conductivity of between 0 and 250 μS/cm as being of a quality that can be used for all agriculturally useful activities; from my experience, the TDS and salinity for fresh water are less than 1999 mg/l and 0-0.5 ppt., respectively (B5). It is in good condition for agriculture (B6). It is in good condition for agriculture (B7). It is perfect for agriculture according to the PWA standard (B8).
2) Question and Condition: Conductivity is 300 μS/cm, total dissolved solid is 2000 mg/L, and salinity is 2.5 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of agriculture?

- Excellent for agriculture (A7)
- Hazardous for sensitive crop (A2, A3, B1, B4, B5)
- Hazardous for low tolerance crop (A6, B3, B7)
- Hazardous for high tolerance crop (A5, B2, B6, B8)
- Satisfactory for livestock and poultry
- Hazard for Poultry
- Unfit for agriculture (A1)
- Suddenly toxic for agriculture

The reason, comment, and feedback: Salinity may be too high (A1). The parameters given in the question are not sufficient to justify an answer, and the parameters do not include heavy metal ions and pesticides (A4). It is in bad condition for a low tolerance crop (B3). The USSL (USSL, 1954) has classified a conductivity of between 250 and 750 μS/cm as being of a sufficient quality to be useful for all agricultural activities except low tolerance salinity plants; from my experience,

the TDS and salinity for fresh water are less than 1999 mg/l and 0.5-3.0 ppt., and salinity may thus impact sensitive crops (B5). These conditions are useful for agriculture (B6). It is not a good condition for a low tolerance crop (B7). The TDS should be less than 600 mg/l according to the PCD standard (B8).
3) Question and Condition: Conductivity is 650 μS/cm, total dissolved solid is 4000 mg/L, and salinity is 4.5 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of agriculture?

- Excellent for agriculture
- Hazardous for sensitive crop (A3, A7)
- Hazardous for low tolerance crop (A2)
- Hazardous for high tolerance crop (B1, B3, B4, B5, B7)
- Satisfactory for livestock and poultry (B2, B6)
- Hazard for Poultry
- Unfit for agriculture (A1, A6, B8)
- Suddenly toxic for agriculture (A5)

The reason, comment, and feedback: High salt content (A1). The parameters given in the question are not sufficient to justify an answer; the parameters do not include heavy metal ions and pesticides (A4). It is in bad condition for a high tolerance crop (B3), the TDS is high (B4), The USSL (USSL, 1954) has classified a conductivity of between 750 and 2250 μS/cm as useful for good tolerance salinity plants which is why the farmers always dilute the crop areas with fresh water; from my experience, the TDS and salinity for fresh water are more than 4000 mg/l and 3.0-5.0 ppt., those will impact a high tolerance crop (B5). These conditions are useful for livestock and poultry (B6). The TDS is far too high for a high tolerance crop (B7). The TDS should less than 600 mg/l according to the PCD standard (B8).
4) Question and Condition: Conductivity is 20000 μS/cm, total dissolved solid is 15000 mg/L, and salinity is 30 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of agriculture?

- Excellent for agriculture

- Hazardous for sensitive crop
- Hazardous for low tolerance crop
- Hazardous for high tolerance crop
- Satisfactory for livestock and poultry
- Hazard for Poultry (B6, B7)
- Unfit for agriculture (A1, A2, A7, B1)
- Suddenly toxic for agriculture (A5, A6, B2, B3, B4, B5, B8)

The reason, comment, and feedback: Salinity is too high (A1). The parameters given in the question are not sufficient to justify an answer, the parameters do not include heavy metal ions and pesticides (A4). These are quite high, definitely toxic for agriculture (B3). All of the parameters are high and might be toxic for living organisms (B4). These ranges of conductivity, TDS, and salinity will be harmful for every type of agricultural crop based on my experience (B5). These conditions are unsafe for poultry (B6). The conductivity and TDS have high values for agriculture (B7). This water isn't optimum for agriculture (B8).

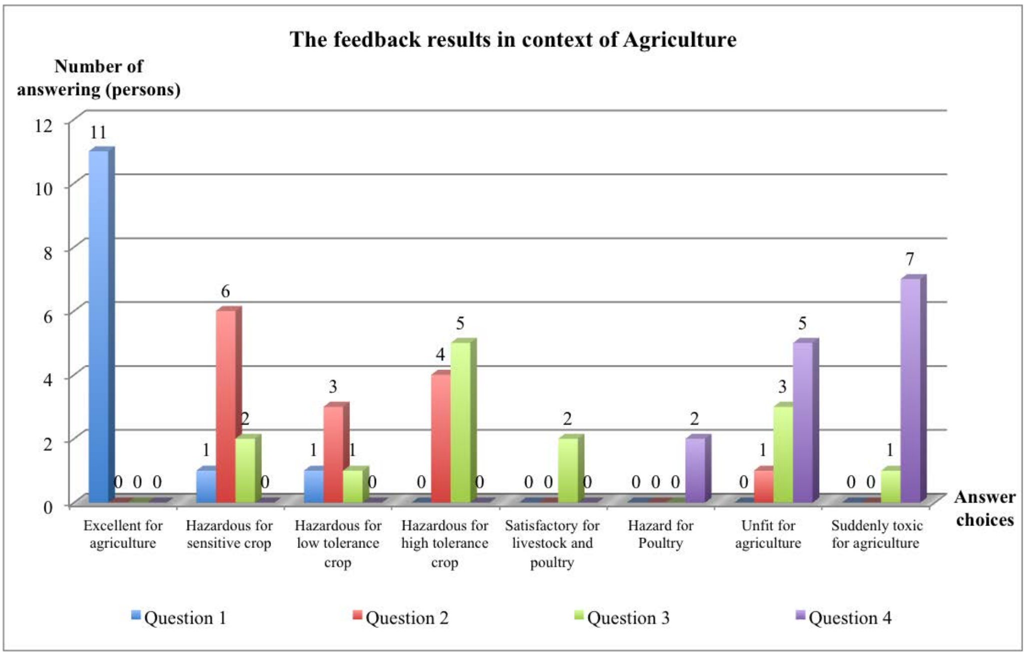

Fig. 7.5 The feedback results in context of Agriculture

Context of Aquatic life

This subsection summarized the results from the specialists using the answers in the context of aquatic life. The feedback results are shown in Figure 7.6 and are described in detail below

5) Question and Condition: Dissolved oxygen (DO) is more than 7.0 mg/L. From the characteristics of dissolved oxygen, which is the appropriate measurement in the context of aquatic life?

- Abundant for aquatic life (A2, A4, A5, A6, B1, B2, B3, B5, B6, B7, B8)
- Support growth and activity for aquatic life (A1, A7, B4)
- Support spawning
- Hazardous for aquatic life
- All aquatic life extinction

The reason, comment, and feedback: Good for aquatic life (A1). As long as this condition is not due to a high algae content, because if the algae concentration is high, it might give a high DO during the daytime (A2). This value of DO (7.0 mg/l) is a saturated condition of DO in nature due to the solids dissolved in the water (A4). Literally good for aquatic life (B3). In my experience and according to the Thai National Standard, a DO of between 6.0 and 7.0 mg/l is fit for all aquatic life (B5). There is enough oxygen in the water for aquatic life usage (B6). The DO is sufficient for aquatic life growth (B7). This value is higher than the minimum accepted DO value according to the PCD standard (B8).

6) Question and Condition: Dissolved oxygen (DO) is 6.0 mg/L. From the characteristics of dissolved oxygen, which is the appropriate measurement in the context of aquatic life?

- Abundant for aquatic life (A3, B5)
- Support growth and activity for aquatic life (A1, A2, A4, A5, A6, B1, B2, B3, B4, B6, B7)
- Support spawning (A7)
- Hazardous for aquatic life
- All aquatic life extinction

The reason, comment, and feedback: Good for aquatic life (A1). Good for aquatic life (B3). My experience and the Thai National Standard indicate that a DO between 6.0 and 7.0 mg/l is fit for all aquatic life (B5). It is a good condition for

aquatic life (B6). The DO is sufficient for aquatic life growth (B7).
7) Question and Condition: Dissolved oxygen (DO) is 3.5 mg/L. From the characteristics of dissolved oxygen, which is the appropriate measurement in the context of aquatic life?

- Abundant for aquatic life
- Support growth and activity for aquatic life (A1)
- Support spawning (A2, A4, A6, B1, B3, B4, B5)
- Hazardous for aquatic life (A5, A7, B2, B6, B7, B8)
- All aquatic life extinction

The reason, comment, and feedback: DO level is good (A1). This condition might be still support spawning, but it is rather difficult to generalize (A2). I cannot answer for this because it is not my expertise (A3). This condition supports spawning (B3). According to the Thai National Standard, a DO of between 2.0 and 4.0 mg/l is provided by water quality standard type 3-4 which is used for consumption (with pre-treatment) and industry (B5). This condition is unsafe for aquatic life growth (B6). The DO is not sufficient for aquatic life growth (B7). The DO is lower than the accepted value according to the PCD standard (B8).
8) Question and Condition: Dissolved oxygen (DO) is 2.0 mg/L. From the characteristics of dissolved oxygen, which is the appropriate measurement in the context of aquatic life?

- Abundant for aquatic life
- Support growth and activity for aquatic life
- Support spawning (A1)
- Hazardous for aquatic life (A2, A5, A6, B1, B3, B4, B5)
- All aquatic life extinction (A4, A7, B2, B6, B7, B8)

The reason, comment, and feedback: DO level is good (A1). Some species survive in this condition but there is not sufficient choice for an answer (A3). It is a good condition for survival but does not support growth and spawning (B3). According to the Thai National Standard, a DO of less than 2.0 mg/L is provided by water quality standard type 5, which is used for transportation activities (B5). There is not enough oxygen to support aquatic life growth (B6). The DO value is very low

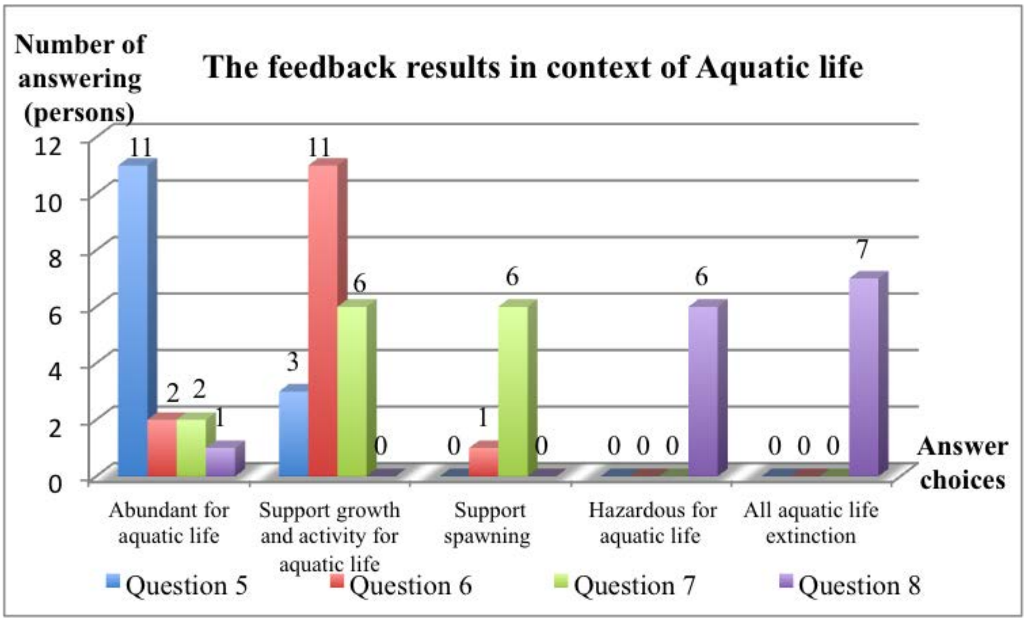

Fig. 7.6 The feedback results in context of Aquatic life

(B7). There is less oxygen than standard, not enough for aquatic life to live (B8).

Context of Drinking

This subsection summarized the results from the specialists using the answers in the context of drinking. The feedback results are shown in Figure 7.7 and are described in detail below

9) Question and Condition: Potential of hydrogen ion (pH) is 8.6, total dissolved solid is 599 mg/L, and turbidity is 4.5 NTU. From the characteristics of pH, total dissolved solid, and turbidity, which are the appropriate measurements in the context of drinking?

- Optimum for drinking (A7, B1)
- Hazardous and chronic for drinking (A2, A4, A5, A6, B2, B3, B6, B7, B8)
- Unfit and toxic for drinking (A1, B4, B5)

The reason, comment, and feedback: It has too high a turbidity (A1). It is rather difficult to answer but it may be hazardous and chronic (A2). The TDS of 599 mg/l slightly exceeds the value of the TDS standard for water supply (A4). I cannot understand the meaning of "chronic for drinking" (A6). Bad for human health (B3). In my experience, the best pH for drinking water should be 6.5-8.5 (B5). The value of pH and TDS are too high for drinking (B6). The alkalinity is too high for drinking water (B7). A fit pH for drinking water is 6.5-8.5 (B8).

10) Question and Condition: Potential of hydrogen ion (pH) is 7.0, total dissolved solid is 110 mg/L, and turbidity is 1.0 NTU. From the characteristics of pH, total dissolved solid, and turbidity, which are the appropriate measurements in the context of drinking?

- Optimum for drinking (A1, A2, A4, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
- Hazardous and chronic for drinking (A5)
- Unfit and toxic for drinking

The reason, comment, and feedback: pH level is good (A1). Good for drinking (B3), suitable for drinking (B4). In my experience the best pH for drinking water should be 6.5-8.5, the TDS should be 300-600 mg/l and turbidity should be 4-9 NTU (B5). It is in safe condition for drinking (B6). It is in optimum condition for drinking water (B7). Acceptable for drinking water (B8).
11) Question and Condition: Potential of hydrogen ion (pH) is 9.5, total dissolved solid is 1000 mg/L, and turbidity is 10.0 NTU. From the characteristics of pH, total dissolved solid, and turbidity, which are the appropriate measurements in the context of drinking?

- Optimum for drinking
- Hazardous and chronic for drinking (A2, B1, B5)
- Unfit and toxic for drinking (A1, A4, A5, A6, A7, B2, B3, B4, B6, B7, B8)

The reason, comment, and feedback: pH and TDS are too high (A1). It is also rather difficult to generalize (A2). The levels of these parameters are quite high, and are surely toxic to human health (B3). Highly toxic (B4). In my experience, these range are not fit for drinking water. A small degree of physical harmful may occur to humans after drinking (B5). The values of pH, TDS, and turbidity are too high and cannot be used for drinking (B6). All parameters are higher than the standard (B7). The TDS should be less than 500 mg/L according to the PCD standard (B8).

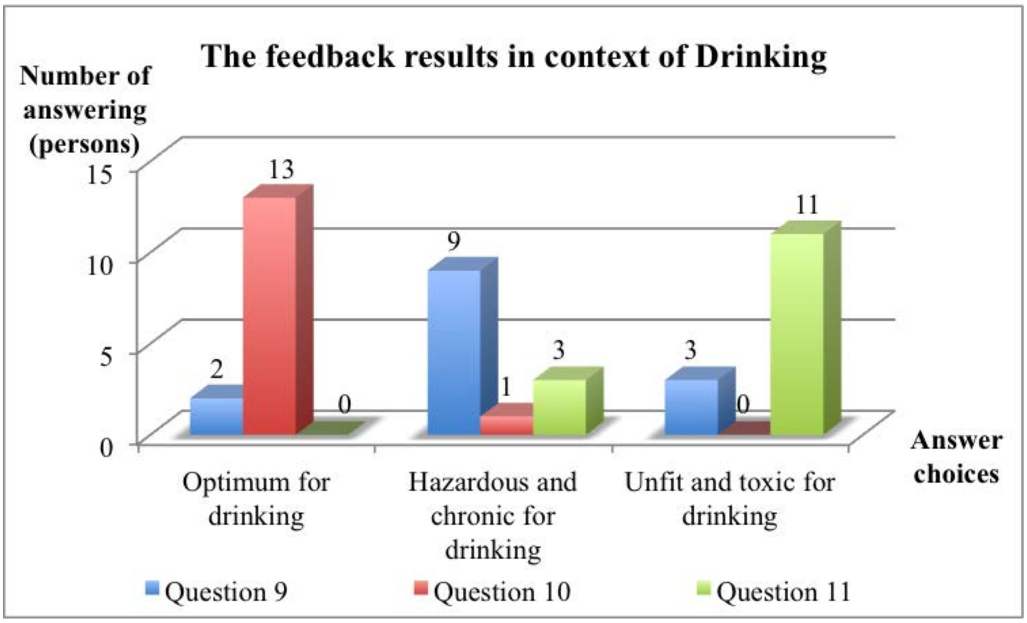

Fig. 7.7 The feedback results in context of Drinking

Context of Fish

This subsection summarized the results from the specialists using the answers in the context of fish. The feedback results are shown in Figure 7.8 and are described in detail below

12) Question and Condition: Potential of hydrogen ion (pH) is 7. From the characteristics of pH, which is the appropriate measurement in the context of fish?

- Abundant for fish (A5, A6, A7, B1, B2, B3, B5, B7, B8)
- Optimum for fish and shrimp (A1, A2, B4, B6)
- Bacteria and plankton being disappear
- Hazardous for fish and salmon dying
- All fish extinction (A4)

The reason, comment, and feedback: Natural pH (A1). As long as there are no other toxic substances (A2). As there is only one parameter it is not possible to determine the consequences in the context of fish (A4). The pH is 7.0, which is a good condition for fish (B3). According to the Thai National Standard, the pH should be 5-9 for aquatic life (B5). Fish and shrimp can live in this condition (B6). The pH value is suitable for fish (B7). Fish and aquatic life can live in this pH value (B8).

13) Question and Condition: Potential of hydrogen ion (pH) is 4.5. From the characteristics of pH, which is the appropriate measurement in the context of fish?

- Abundant for fish
- Optimum for fish and shrimp (B5)
- Bacteria and plankton being disappear (A2, A6, B2, B3)
- Hazardous for fish and salmon dying (A4, A7, B1, B4, B6, B7, B8)
- All fish extinction (A1, A5)

The reason, comment, and feedback: pH is an acidic condition (A1). For a start it has some effects on microorganisms (A2). It is a bad condition for bacteria and plankton (B3). In my experience, a pH of between 4.0 and 4.5 is optimum for shrimp (B5). It is an acidic condition (B6). The pH value is an acidic condition (B7). Fish and aquatic life cannot live in this quite acidic condition (B8).
14) Question and Condition: Potential of hydrogen ion (pH) is 2.5. From the characteristics of pH, which is the appropriate measurement in the context of fish?

- Abundant for fish (A6, B1, B2)
- Optimum for fish and shrimp
- Bacteria and plankton being disappear (A4)
- Hazardous for fish and salmon dying (B3)
- All fish extinction (A1, A2, A5, A7, B4, B5, B7, B8)

The reason, comment, and feedback: Water is in an acidic condition (A1), most of fish cannot live in this pH (A2). It is quite acidic, which is hazardous for all fish (B3). In my experience, a pH of less than 2.5 is of high acidity, fish may not live in this condition (B5). It is a strongly acid condition (B6). It is a too acidic condition for fish (B7). It is a bad condition for fish and aquatic life to live in (B8).
15) Question and Condition: Potential of hydrogen ion (pH) is 6.2. From the characteristics of pH, which is the appropriate measurement in the context of fish?

- Abundant for fish
- Optimum for fish and shrimp (A2, A4, A6, A7, B1, B2, B3, B4, B6, B7, B8)

- Bacteria and plankton being disappear (B5)
- Hazardous for fish and salmon dying (A1, A5)
- All fish extinction

The reason, comment, and feedback: It is too low a pH level (A1). It is not the optimum condition, but the microorganisms may survive (A2). Fish, shrimp, bacteria, and plankton can survive in this condition (B3). A pH 6-8 is optimum for fish and shrimp (B4). In my experience, a pH of less than 2.5 is high acidic, a small acidity of around 6.2-6.9 is not fit for bacteria (B5). This is fit for fish and shrimp (B6). This condition is acceptable for fish and shrimp (B7). The optimum pH for fish and aquatic life to live in is between 5-9 according to the PCD standard (B8).

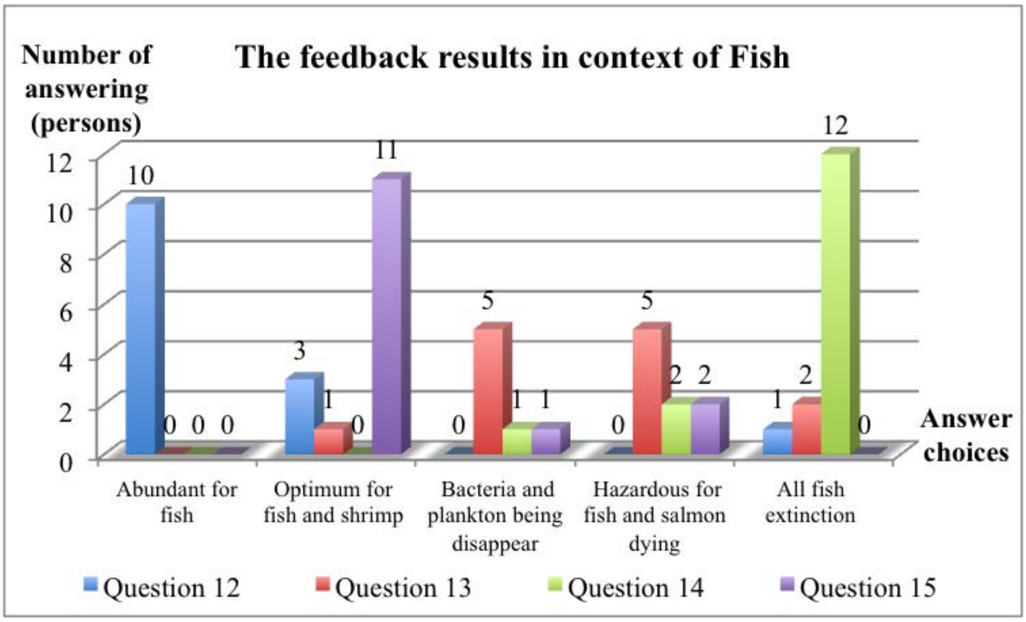

Fig. 7.8 The feedback results in context of Fish

Context of Industry

This subsection summarizes the results from the specialists using the answers in the context of industry. The feedback results are shown in Figure 7.9 and are described in detail below

16) Question and Condition: Conductivity is 20 μS/cm, pH is 7.3, total dissolved solid is 199 mg/L. From the characteristics of conductivity, pH, and total dissolved solid, which are the appropriate measurements in the context of industry?

- Optimum for industrial process (A2, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
- Slightly corrosive scaling and fouling (A4, A5)
- Moderate corrosive scaling and fouling (A1)
- Highly corrosive scaling and fouling
- Unfit for industrial process

The reason, comment, and feedback: TDS is too high (A1). It is optimum for an industry context (A2). It is very good for all equipment (B3). Based on the National Standard (B5). Accepted for industrial processes usage (B6). This condition is accepted for industry processes (B7). Accepted for industrial processes usage (B8).

17) Question and Condition: Conductivity is 245 μS/cm, pH is 4.5, total dissolved solid is 1500 mg/L. From the characteristics of conductivity, pH, and total dissolved solid, which are the appropriate measurements in the context of industry?

- Optimum for industrial process
- Slightly corrosive scaling and fouling (A7, B1, B5)
- Moderate corrosive scaling and fouling (A2, A4, A5, A6, B2, B3, B4, B8)
- Highly corrosive scaling and fouling (A1, B6, B7)
- Unfit for industrial process

The reason, comment, and feedback: pH is in an acidic condition (A1). Corrosive, which is bad for all equipment (B3). Based on the National Standard (B5). It is an acid condition (B6). It is an acidic condition and can cause corrosion in industry processes (B7). The pH value is in the slightly acidic range, it may be a cause of equipment corrosion (B8).

18) Question and Condition: Conductivity is more than 1000 μS/cm, pH is less than 2.9, total dissolved solid is more than 7500 mg/L. From the characteristics of conductivity, pH, and total dissolved solid, which are the appropriate measurements in the context of industry?

- Optimum for industrial process
- Slightly corrosive scaling and fouling

- Moderate corrosive scaling and fouling
- Highly corrosive scaling and fouling (A1, A2, A4, A7, B1, B3, B5, B8)
- Unfit for industrial process (A5, A6, B2, B4, B6, B7)

The reason, comment, and feedback: pH is in an acidic condition (A1). Bad for all equipment (B3). Based on the National Standard (B5). It is a strongly acid condition and has too a high conductivity and TDS (B6). It is a bad condition for industry processes (B7). This condition is bad for industry processes (B8).
19) Question and Condition: Conductivity is 35 μS/cm, pH is 6.3, total dissolved solid is 300 mg/L. From the characteristics of conductivity, pH, and total dissolved solid, which are the appropriate measurements in the context of industry?

- Optimum for industrial process (A4, A7, B1, B4, B5)
- Slightly corrosive scaling and fouling (A2, A6, B2, B3, B6, B7, B8)
- Moderate corrosive scaling and fouling (A1)
- Highly corrosive scaling and fouling (A5)
- Unfit for industrial process

The reason, comment, and feedback: pH is slightly low (A1), it is a good for all equipment (B3). Based on the National Standard (B5). It is not good for industry process usage (B6). The pH value is a slightly acidic condition (B7). There is potential for equipment corrosion (B8).

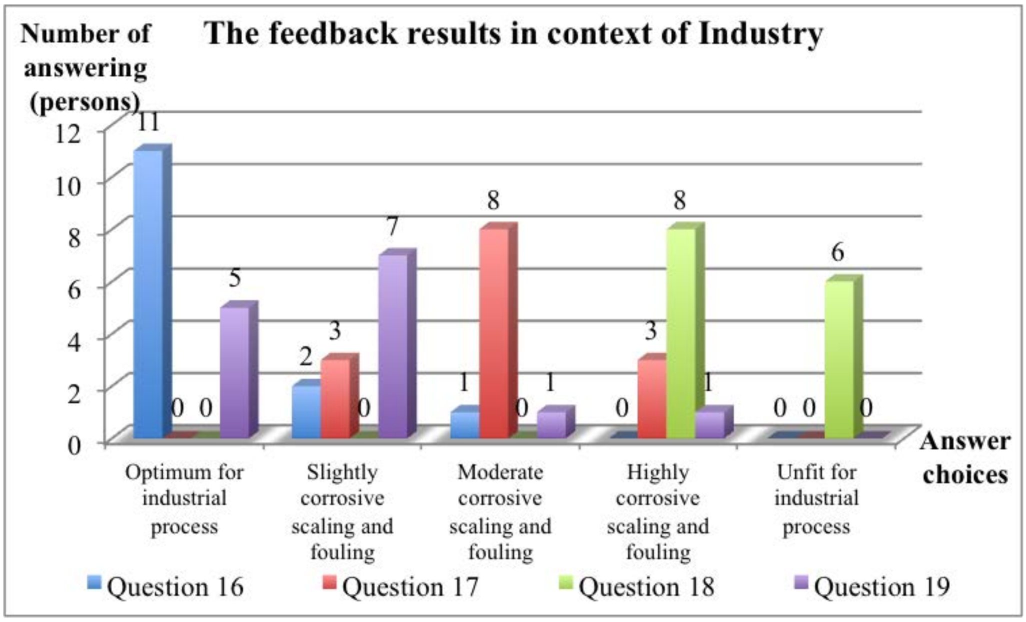

Fig. 7.9 The feedback results in context of Industry

Context of Irrigation

This subsection summarizes the results from the specialists using the answers in the context of irrigation. The feedback results are shown in Figure 7.10 and are described in detail below

20) Question and Condition: Conductivity is less than 60 μS/cm, total dissolved solid is less than 350 mg/L, and salinity is less than 0.40 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of irrigation?

- Excellent for irrigation (A2, A4, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
- Moderate hazardous for irrigation (A1, A5)
- Hazard for irrigation

The reason, comment, and feedback: TDS is too high (A1). Conductivity, total dissolved solid, and salinity, these are brilliant for irrigation (B3). Based on the National Standard (B5). It is suitable for irrigation usage (B6). This condition is accepted for irrigation (B7). It is a good condition for irrigation (B8).

21) Question and Condition: Conductivity is 150 μS/cm, total dissolved solid is 1500 mg/L, and salinity is 1.9 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of irrigation?

- Excellent for irrigation (A7)

- Moderate hazardous for irrigation (A2, A4, A6, B1, B2, B3, B4, B5, B6, B7, B8)
- Hazard for irrigation (A1, A5)

The reason, comment, and feedback: Salinity is too high (A1). Conductivity, total dissolved solid, and salinity, these are quite hazardous for irrigation (B3). Based on the National Standard (B5). All parameters are too high for irrigation, these will effect to living life (B6). This condition is highly unacceptable for irrigation (B7). It is a bad condition for irrigation usage (B8).
22) Question and Condition: Conductivity is more than 5000 μS/cm, total dissolved solid is more than 7500 mg/L, and Salinity is more than 10 ppt. From the characteristics of conductivity, total dissolved solid, and salinity, which are the appropriate measurements in the context of irrigation?

- Excellent for irrigation
- Moderate hazardous for irrigation (A7)
- Hazard for irrigation (A1, A2, A4, A5, A6, B1, B2, B3, B4, B5, B6, B7, B8)

The reason, comment, and feedback: Salinity is too high (A1). Conductivity, total dissolved solid, and salinity, these are quite hazardous for irrigation (B3). Based on the National Standard (B5). All parameters are too high for irrigation, these are effect to living life (B6). This condition is strongly unaccepted for irrigation (B7). It is bad condition for irrigation usage (B8).

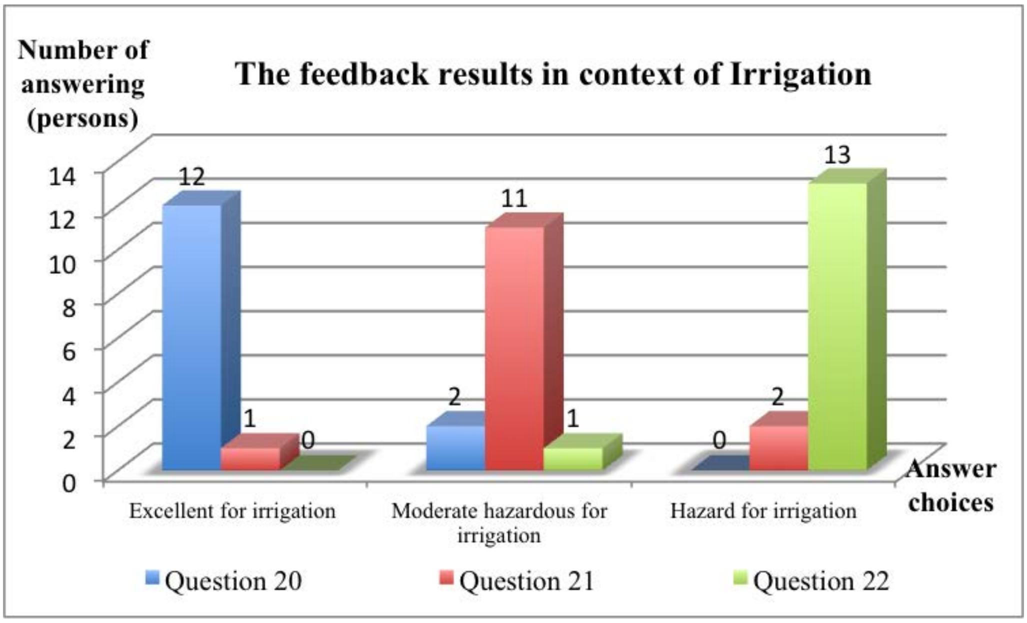

Fig. 7.10 The feedback results in context of Irrigation

Context of Recreation

This subsection summarizes the results from the specialists using the answers in the context of recreation. The feedback results are shown in Figure 7.11 and are described in detail below

23) Question and Condition: E. coli 90 CFU/100 mL, Enterococci 30 CFU/100 mL, and Coliform bacteria 200 CFU/100 mL. From the characteristics of E. coli, Enterococci, and Coliform bacteria, which are the appropriate measurements in the context of recreation?

(The international standard value of microbial: E. coli 126 CFU/100 mL, Enterococci 35 CFU/100 mL., and Coliform bacteria 400 CFU/100 mL, from US-EPA and EU Directive 76/160/EEC by geometric mean method)

- Little risk of illness (A2, A4, A6, B1, B2, B3, B4, B5, B6, B7, B8)
- Moderate risk of illness (A1, A5)
- Critical risk of illness
- Strong risk of illness
- Excessively risk of illness (A7)

The reason, comment, and feedback: Coliform bacteria is too high (A1). This condition still has some risk, although it might be rather small (A2). All values in the question are better than the standard (A4). Low risk of illness (B3). Based on the National Standard, US-EPA, and EU Directive 76/160/EEC by the geometric mean method (B5). Acceptable for usage (B6). The amount of bacteria is acceptable (B7). According to the PDC standard, the best condition is that there are no bacteria in the water (B8).

24) Question: Condition: E. coli 150 CFU/100 mL, Enterococci 300 CFU/100 mL, and Coliform bacteria 500 CFU/100 mL. From the characteristics of E. coli, Enterococci, and Coliform bacteria, which are the appropriate measurements in the context of recreation?

(The international standard value of microbial: E. coli 126 CFU/100 mL, Enterococci 35 CFU/100 mL, and Coliform bacteria 400 CFU/100 mL from US-EPA and EU Directive 76/160/EEC by geometric mean method)

- Little risk of illness (A4)
- Moderate risk of illness (A2, B1, B2, B3, B4, B6, B7, B8)
- Critical risk of illness (A5, A6, B5)
- Strong risk of illness (A1)
- Excessively risk of illness (A7)

The reason, comment, and feedback: Coliform bacteria are too high (A1). Is it correct that the coliform bacteria count was 500 CFU/100 mL? (A4). Moderate risk of illness (B3). Based on the National Standard, US-EPA, and EU Directive 76/160/EEC by the geometric mean method (B5). This condition may cause disease (B6). This amount of bacteria may cause illness (B7). It may affect humans and can cause illness (B8).

25) Question: Condition: E. coli 10000 CFU/100 mL, Enterococci 9000 CFU/100 mL, and Coliform bacteria 500000 CFU/100 mL. From the characteristics of E. coli, Enterococci, and Coliform bacteria, which are the appropriate measurements in the context of recreation?

(The international standard value of microbial: E. coli 126 CFU/100 mL, Enterococci 35 CFU/100 mL, and Coliform bacteria 400 CFU/100 mL from US-EPA and EU Directive 76/160/EEC by geometric mean method)

- Little risk of illness
- Moderate risk of illness
- Critical risk of illness (A4, B1, B2, B3, B6, B7, B8)
- Strong risk of illness (A2, A5, A6, B5)

- Excessively risk of illness (A1, A7, B4)

The reason, comment, and feedback: Coliform bacteria is too high (A1). Is it correct that the coliform bacteria was 500000 CFU/100 mL? (A4). High numbers of bacteria, which gives a critical risk of illness (B3). Based on the National Standard, US-EPA, and EU Directive 76/160/EEC by the geometric mean method (B5). The amount of bacteria is more than the standard and it can be the cause of illness (B6). This amount of bacteria may cause illness (B7). This condition cannot be used for recreation (B8).
26) Question: Condition: E. coli 10000 CFU/200000 mL, Enterococci 52000 CFU/100 mL, and Coliform bacteria 2000000 CFU/100 mL. From the characteristics of E. coli, Enterococci, and Coliform bacteria, which are the appropriate measurements in the context of recreation?
(The international standard value of microbial: E. coli 126 CFU/100 mL, Enterococci 35 CFU/100 mL, and Coliform bacteria 400 CFU/100 mL, from US-EPA and EU Directive 76/160/EEC by geometric mean method)

- Little risk of illness
- Moderate risk of illness
- Critical risk of illness
- Strong risk of illness (A1, A4, B2, B3, B6, B7, B8)
- Excessively risk of illness (A2, A5, A6, A7, B1, B4, B5)

The reason, comment, and feedback: Bacteria is too high (A1). It is not good at all (A2). Quite high numbers of bacteria, which gives a strong risk of illness (B3). Based on the National Standard, US-EPA, and EU Directive 76/160/EEC by the geometric mean method (B5). It cannot be acceptable and causes illness (B6). This amount of bacteria exceeds the standard (B7). It is a bad condition for recreation (B8).

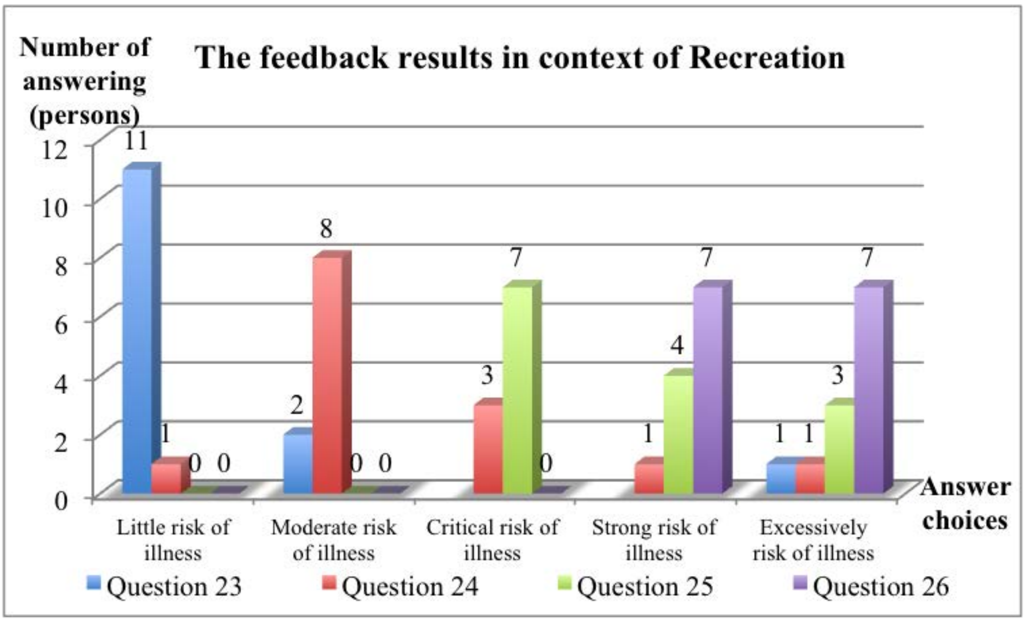

Fig. 7.11 The feedback results in context of Recreation

Heavy metal parameters

Context of Aquatic life (heavy metal)
This subsection summarized the results from the specialists using the answers in the context of aquatic life (heavy metal parameters). The feedback results are shown in Figure 7.12 and are described in detail below
27) Question and Condition: Arsenic is less than 10 μg/L, Cadmium is less than 1 μg/L, Chromium is less than 1 μg/L, Copper is less than 4 mg/L, Iron is less than 300 mg/L, Lead is less than 7 mg/L, Mercury is less than 0.003 μg/L, Nickel is less than 25 μg/L, and Zinc is less than 5 mg/L. Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc, which are the appropriate meaning in the context of aquatic life?

- Safe for aquatic life (A2, A6, B1, B2, B3, B4, B5, B6, B7, B8)
- Threshold toxic for aquatic life (A1, A4, A5, A7)

The reason, comment, and feedback: Heavy metals are too high (A1). Generally it is safe, however, the ion content is very high and this is not common. These data might be wrong (A2). It is safe for aquatic life (B3). According to the Department of Fisheries, Thailand (B.E. 2530), heavy metals content of Cd, Cu, Pb, Hg, Fe, and Zn should not exceed 1 μg/L, 0.02 mg/L, 0.05 mg/L, 0.5 μg/L, 0.3 mg/L, and 0.1 mg/L respectively for aquatic life (B5). This could be acceptable for aquatic life growth (B6). This could be acceptable for aquatic life (B7). All values are less than the PCD standard (B8).

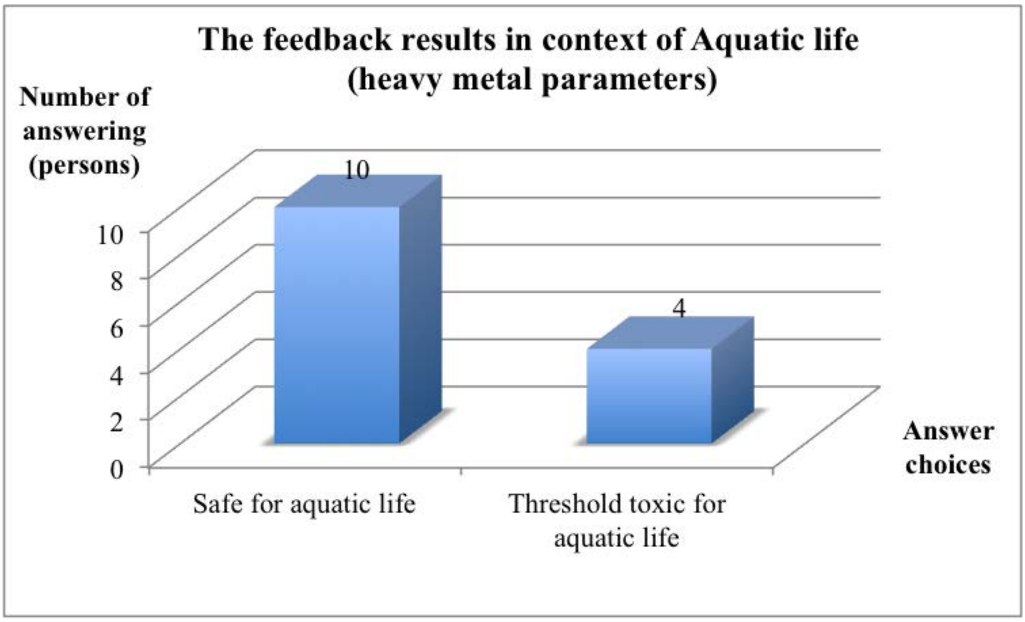

Fig. 7.12 The feedback results in context of Aquatic life (heavy metal parameters)

Context of Livestock and Wildlife (heavy metal)

This subsection summarized the results from the specialists using the answers in the context of livestock and wildlife (heavy metal parameters). The feedback results are shown in Figure 7.13 and are described in detail below

28) Question and Condition: Arsenic is 30 μg/L, Cadmium is 50 μg/L, Chromium is less than 1000 μg/L, Copper is less than 1000 mg/L, Iron is less than 100 mg/L, Lead is less than 50 mg/L, and Mercury is less than 1 μg/L. Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc, which are the appropriate meaning in the context of Livestock and Wildlife?

- Satisfactory for Livestock and Wildlife (B1, B2, B4, B5, B6, B7, B8)
- Threshold toxic for Livestock and Wildlife (A1, A2, A4, A5, A6, A7, B3, B5)

The reason, comment, and feedback: This condition may be toxic to animals (A1). Copper, iron, and lead are high (A2). The high level of heavy metals is toxic to livestock and wildlife (B3). According to the Department of Fisheries, Thailand (B.E. 2530), the heavy metals content for Cd, Cu, Pb, Hg, Fe, and Zn should not exceed 1 μg/L, 0.02 mg/L, 0.05 mg/L, 0.5 μg/L, 0.3 mg/L, and 0.1 mg/L respectively for aquatic life (B5). This condition is acceptable (B6). Livestock and wildlife can live in this condition (B7). Acceptable for livestock and wildlife (B8).

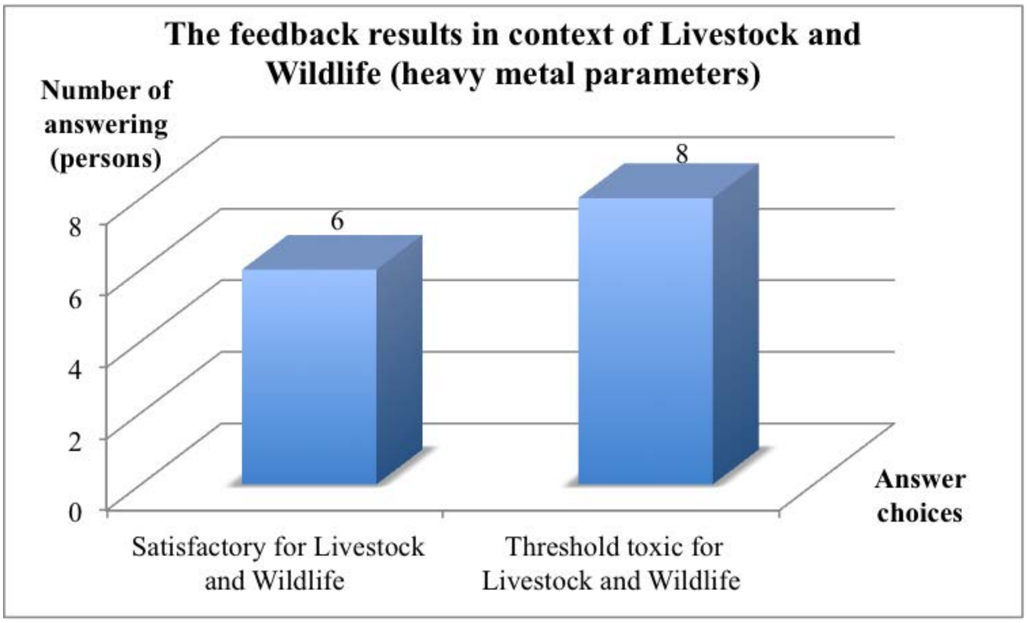

Fig. 7.13 The feedback results in context of Livestock and Wildlife (heavy metal parameters)

Context of Irrigation (heavy metal)

This subsection summarized the results from the specialists using the answers in the context of irrigation (heavy metal parameters). The feedback results are shown in Figure 7.14 and are described in detail below

29) Question and Condition: Arsenic is 1000 μg/L, Cadmium is 1000 μg/L, Chromium is 150 μg/L, Copper is 400 mg/L, Iron is 300 mg/L, Lead is 6000 mg/L, Mercury is 5 μg/L, Nickel is 500 μg/L, and Zinc is 5000 mg/L. Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc, which are the appropriate meaning in the context of irrigation?

- Excellent for irrigation (B1, B4)
- Hazardous for irrigation (A1, A2, A4, A5, A6, A7, B2, B3, B5, B6, B7, B8)

The reason, comment, and feedback: Heavy metals are too high (A1). Copper, iron, lead, and zinc are very high (A2). Quite high levels of heavy metals, which are hazardous to livestock and wildlife (B3). The amount of heavy metals is dangerous for irrigation usage (B6). It is dangerous for irrigation usage (B7). The value of heavy metal content is higher than the maximum acceptable value in the PWA standard (B8).

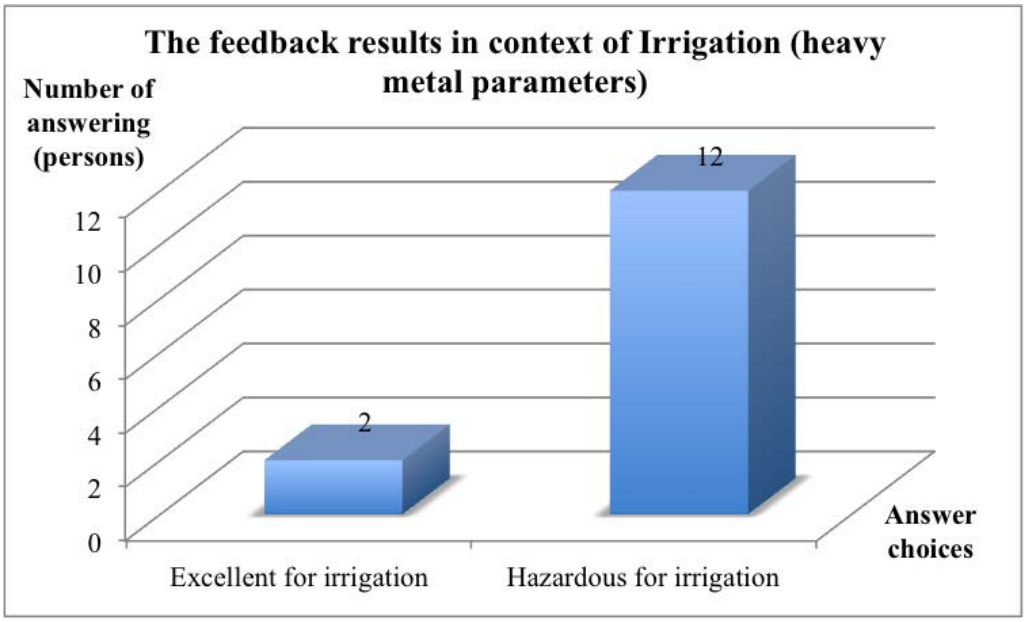

Fig. 7.14 The feedback results in context of Irrigation (heavy metal parameters)

Context of Industry (heavy metal)

This subsection summarized the results from the specialists using the answers in the context of industry (heavy metal parameters). The feedback results are shown in Figure 7.15 and are described in detail below

30) Question and Condition: Arsenic is 250 μg/L, Cadmium is 1000 μg/L, Chromium is 5000 μg/L, Copper is 4000 mg/L, Iron is 3000 mg/L, Lead is 600 mg/L, and Mercury is 10 μg/L. Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc, which are the appropriate meaning in the context of industry?

- Optimum for industrial process (B1, B4)
- Unfit, high corrosive, scaling and fouling for industrial process (A1, A2, A4, A5, A6, A7, B2, B3, B5, B6, B7, B8)

The reason, comment, and feedback: Heavy metals are too high (A1). High metal content but this water might be used after treatment (A2). Unfit, highly corrosive, scaling and fouling for industrial processes (B3). Based on my experience (B5). It may be a cause of equipment damage (B6). The concentration of heavy metals is too high in the water (B7). Unacceptable for industry processes (B8).

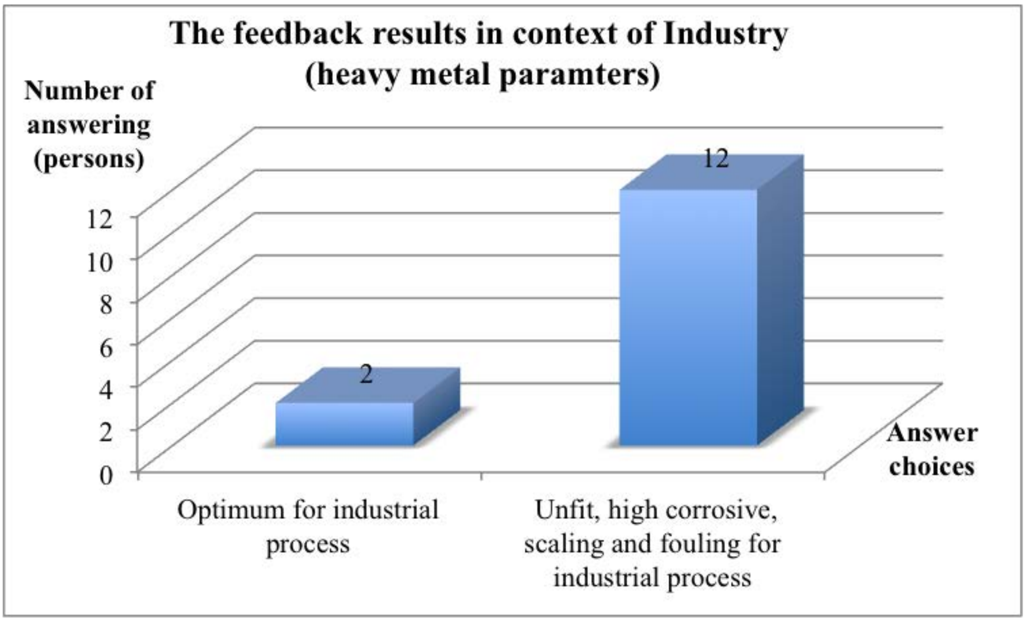

Fig. 7.15 The feedback results in context of Industry (heavy metal parameters)

Context of Estuary Basic Water (heavy metal)

This subsection summarized the results from the specialists using the answers in the context of estuary basic water (heavy metal parameters). The feedback results are shown in Figure 7.16 and are described in detail below

31) Question and Condition: Arsenic is 200 μg/L, Cadmium is 3 μg/L, Chromium is 120 μg/L, Copper is 300 mg/L, Iron is 300 mg/L, Lead is 200 mg/L, Mercury is 0.1 μg/L, Nickel is 100 μg/L, and Zinc is 5000 mg/L. Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, and Zinc, which are the appropriate meaning in the context of Estuary Basic Water?

- Optimum for Estuary Basic Water (A4, B1, B2, B4, B6, B7, B8)
- Damage for Estuary Basic Water (A1, A2, A5, A6, A7, B3, B5)

The reason, comment, and feedback: Heavy metals are too high (A1). High metals content (A2). Damage to estuary basic water (B3). Based on my experience (B5). This condition is acceptable (B6). This condition is acceptable (B7). Accepted for estuary basic water according to the PCD standard (B8).

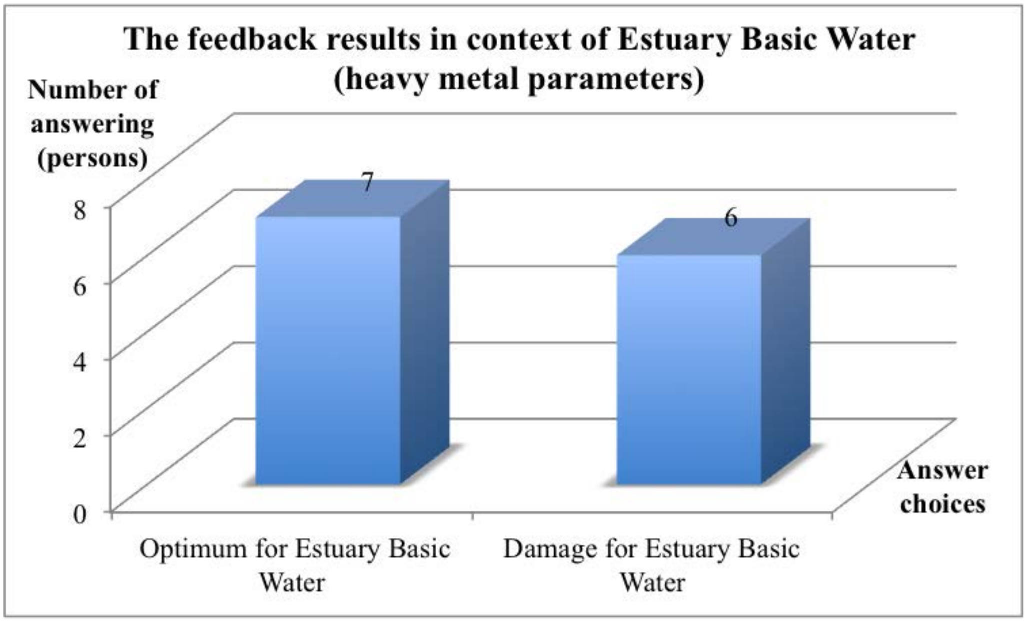

Fig. 7.16 The feedback results in context of Estuary Basic Water (heavy metal parameters)

Rating the results of water-quality

This subsection summarized the rating results of water-quality analysis from the specialists using the answers. The feedback results are shown in Figure 7.17 and are described in detail below

32) Please rate the results of water-quality when results is "Excellent for agriculture" from conductivity is less than 29 μS/cm, total dissolved solid is less than 130 mg/L, and salinity is less than 0.13 ppt.

- Agree (A1, A2, A5, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
  The reason: Good for crops (A1). This condition is excellent for agriculture (B3). Based on my experience and the national standard (B5). It is a good condition for growing for the plants (B6). It is a good condition for agriculture (B7). Accepted for agriculture (B8).

- Not agree (A4)
  The reason:

33) Please rate the results of water-quality when results is "Hazard for aquatic life" from dissolved oxygen is less than 3.1 mg/L.

- Agree (A1, A5, A7, B2, B3, B4, B5, B6, B7, B8)
  The reason: Based on my experience and the national standard (B5). Totally agree, this DO value is hazardous for aquatic life but they can survive (B3).

There is not enough oxygen for aquatic life (B6). The concentration of DO is not suitable for aquatic life (B7). The optimum value of DO in water is between 5-9 mg/L (B8).

- Not agree (A1, A2, A4, A6, B1)
  The reason: Aquatic life may survive (A1). I partly agree, there might be some effect but it may not be hazardous (A2).

34) Please rate the results of water-quality when results is "Unfit and toxic for drinking" from pH is equal 9.5, total dissolved solid is 1000 mg/L, and turbidity is 10.0 NTU.

- Agree (A1, A2, A4, A5, A6, A7, B2, B3, B4, B5, B6, B7, B8)
  The reason: pH is too high (A1). Quite acidic and dirty with TDS (B3). Based on my experience and the national standard (B5). There is too much alkalinity in the water for drinking (B6). This condition has too high an alkalinity (B7). It is a bad condition for drinking water (B8).

- Not agree (B1)
  The reason:

35) Please rate the results of water-quality when results is "Optimum for industry process" from conductivity is 20 μS/cm, pH is 7.3, total dissolved solid is 199 mg/L.

- Agree (A1, A2, A4, A6, A7, B1, B2, B3, B4, B5, B6, B7, B8)
  The reason: Optimum for industrial uses (A1). It is fine in general (A2), this condition is optimum for industry processes (B3). Based on my experience and the national standard (B5). This condition is acceptable for industry processes (B6). Accepted for industry processes (B7). According to the PCD standard, this condition is accepted for industry processes (B8).

- Not agree (A5)
  The reason:

36) Please rate the results of water-quality when results is "Moderate hazard for irrigation" from conductivity is 150 μS/cm, total dissolved solid is 1500 mg/L, and salinity is 1.9 ppt.

- Agree (A1, A2, A4, A5, A6, B1, B2, B3, B4, B5, B6, B7, B8)
  The reason: Crops may survive (A1). This condition is a moderate hazard

for irrigation (B3). Based on my experience and the national standard (B5). TDS is not fit for irrigation (B6). TDS is too high for irrigation (B7). TDS should less than 600 mg/L according to the PCD standard (B8).

- Not agree (A7)
  The reason:

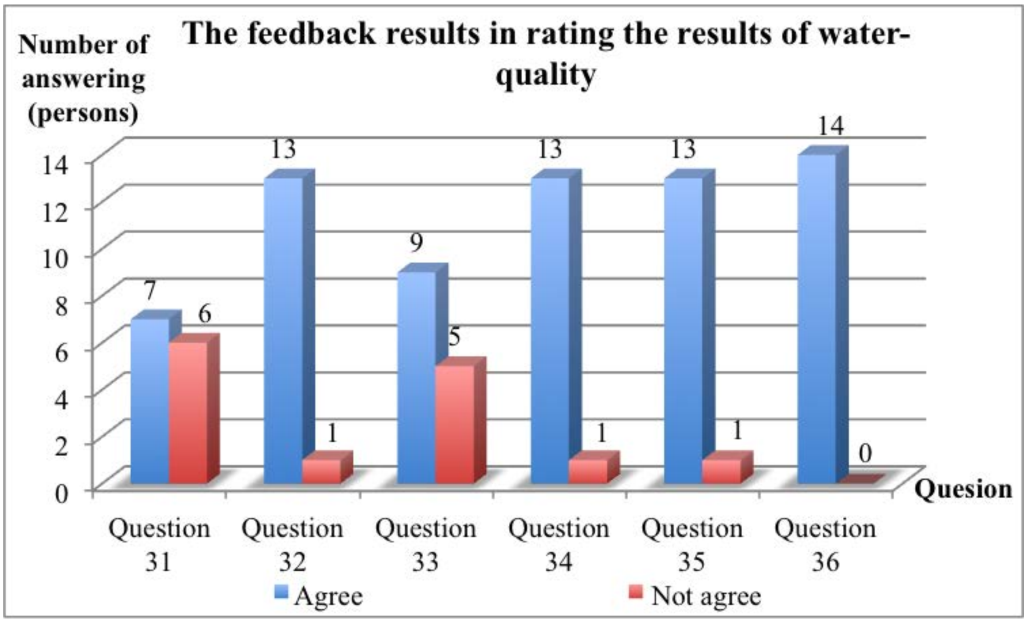

Fig. 7.17 The feedback results in rating results of water-quality analysis

7.3.2 Feedback to the system

Part 1. The reflection of the specialists' knowledge input to the system (to modify the water-quality criteria and classification)

The feedback from the specialist's knowledge is implemented and summarized into the system. The different criteria from the specialists' feedback will be added to the previous criteria (a summary of the design context based on in depth knowledge in the design of the environmental system and water-quality assessment). The results of the specialists' feedback are summarized in below 1.1. The new criteria from the majority of the specialists are shown in table 7.7 and the differences from the previous criteria are described as follows;

- In the context of agriculture. The criteria in classes 2, 3, and 4 are modified. The modifications to class 2 are in $feature_1$ (cond) 30 - 300, $feature_4$ (sal) 0.15 - 2.5, and $feature_5$ (tds) 150 - 2000. The modifications to class 3 are to

$feature_1$ (cond) 301 - 399, $feature_4$ (sal) 2.6 - 2.7, and $feature_5$ (tds) 2001 - 2499, and the modifications to class 4 are to $feature_1$ (cond) 400 - 499, $feature_4$ (sal) 2.8 - 2.9, and $feature_5$ (tds) 2500 - 3199.

- In the context of industry. The criteria in classes 3, 4, and 5 are modified. The modifications to class 3 are to $feature_1$ (cond) 50 - 245, $feature_3$ (pH) 4.5 - 5.9, 9.0 - 9.9, and $feature_5$ (tds) 350 - 1500. The modifications to class 4 are to $feature_1$ (cond) 246 - 1000, $feature_3$ (pH) 2.9 - 4.4, 10.0 - 11.9, and $feature_5$ (tds) 1501 - 7500, and the modifications to class 5 are to $feature_1$ (cond) more than 1001, $feature_3$ (pH) 0.0 - 2.8, 12.0 - 14.0, and $feature_5$(tds) 7501 - 10000.

- In the context of recreation. The criteria in classes 4 and 5 are modified. The modifications to class 4 are to $feature_7$ (E. coli) 10001 - 80000, $feature_8$ (coliform bacteria) 100001 - 1000000, and $feature_9$ (Enterococci) 4001 - 30000, and the modifications to class 5 are to $feature_7$ (E. coli) 80001 - 1000000, $feature_8$ (Coliform bacteria) 1000001 - 10000000, and $feature_9$ (Enterococci) 30001 - 100000.

1.2 The new criteria from the minority answering part of the specialist's knowledge is shown in table 7.8 and the differences from the previous criteria are described as follows;

- In the context of agriculture. The criteria in classes 3, 4, 7, and 8 are modified. The modifications to class 3 are to $feature_1$ (cond) 75 - 300, $feature_4$ (sal) 0.5 - 2.5, and $feature_5$ (tds) 500 - 2000. The modifications to class 4 are to $feature_1$ (cond) 301 - 499, $feature_4$ (sal) 2.6 -2.9, and $feature_5$ (tds) 2001 - 3199. The modifications to class 7 are to $feature_1$ (cond) 2000 - 20000, $feature_4$ (sal) 7.0 - 30.0, and $feature_5$ (tds) 7040 - 15000, and the modifications to class 8 are to $feature_1$ (cond) 20001 - 50000, $feature_4$ (sal) 31.0 - 50.0, and $feature_5$ (tds) 15001 - 20000.

- In the context of aquatic life. The criteria in classes 1 and 2 are modified. The modification to class 1 is to $feature_2$ (DO) 7.1 - 15.0, and the modification to class 2 is to feature2 (DO) 6.0 - 7.0.

- In the context of drinking water. The criteria in classes 1, 2, and 3 are modified. The modifications to class 1 are to $feature_3$ (pH) 6.5 - 8.6, $feature_5$ (tds) 0.0 - 599, and $feature_6$ (turb) 0.0 - 4.5. The modifications to class 2 are to $feature_3$ (pH) 5.0 - 6.4, 8.7 - 9.5, $feature_5$ (tds) 600 - 1000, and $feature_6$ (turb) 4.6 - 10.0, and the modifications to class 3 are to $feature_3$

Table 7.7 The feedback context based on specialist's knowledge in water-quality analysis field (A).

Context	Feature$_1$ (Cond)	Feature$_2$ (DO)	Feature$_3$ (pH)	Feature$_4$ (Sal)	Feature$_5$ (TDS)	Feature$_6$ (Turb)	Feature$_7$ (E. coli)	Feature$_8$ (Coliform bacteria)	Feature$_9$ (Enterococci)	Semantic meaning
Agriculture	0 – 29			0-0.14	0-149					Excellent for agriculture
	30 – 300			0.15-2.5	150-2000					Hazard for sensitive crop
	301 – 399			2.6-2.7	2001-2499					Hazard for low tolerance crop
	400 - 499			2.8-2.9	2500-3199					Hazard for high tolerance crop
	500-749			3.0-4.9	3200-5119					Satisfactory for livestock and poultry
	750-1999			5.0-6.9	5200-7039					Hazard for poultry
	2000-15999			7.0-9.9	7040-10239					Unfit for agriculture
	16000-50000			10-50	10240-20000					Suddenly toxic for agriculture
Aquatic life		7.0 -15								Abundant aquatic life
		6.0 - 6.9								Support growth and activity for aquatic life
		5.0 – 5.9								Support spawning
		3.0 – 4.9								Hazard for aquatic life
		0.0 – 2.9								All aquatic life extinction
Drinking			6.5-8.4		0-199	0-1.9				Optimum for drinking
			5.0-6.4, 8.5-9.1		200-599	2.0-4.9				Hazard and chronic toxic for drinking
			0.0-4.9 9.2-14		600-1000	5.0-10.0				Unfit and toxic for drinking
Fish			6.5-8.1							Abundant for fish
			6.0-6.4							Optimum for fish and shrimp
			5-5.9							Bacteria and plankton being disappear
			4.0-4.9, 8.2-10.4							Hazard for fish and salmon dying
			0-3.9, 10.5-14.0							All fish extinction
Industry	0-29		6.5-7.9		0-199					Optimum for industrial process
	30-49		6.0-6.4, 8.0-8.9		200-349					Slightly corrosive scaling and fouling
	50-245		4.5-5.9, 9.0-9.9		350-1500					Moderate corrosive scaling and fouling
	246-1000		2.9-4.4, 10.0-11.9		1501-7500					Highly corrosive scaling and fouling
	> 1001		0.0-2.8, 12.0-14.0		7501-10000					Unfit for industrial process
Irrigation	0-69			0-0.4	0-499					Excellent for irrigation
	70-299			0.5-1.9	500-1999					Moderate hazard for irrigation
	300-10000			2.0-15.0	2000-10000					Hazard for irrigation
Recreation							0-100	0-500	0-40	Litter risk of illness
							101-1000	501-10000	41-400	Moderately risk of illness
							1001-10000	10001-100000	401-4000	Critical risk of illness
							10001-80000	100001-1000000	4001-30000	Strongly risk of illness
							80001-1000000	1000001-10000000	30001-100000	Excessively risk of illness

(pH) 0.0 - 4.9, 9.6 - 14.0, $feature_5$ (tds) more than 1001, and $feature_6$ (turb) 10.0 - 15.0.

- In the context of fish. The criteria in classes 1, 2, 3, 4, and 5 are modified. The modification to class 1 is to $feature_3$ (pH) 7.1 - 8.1. The modification to class 2 is to $feature_3$ (pH) 6.3 - 7.0. The modification to class 3 is to $feature_3$ (pH) 4.5 - 6.2. The modifications to class 4 are to $feature_3$ (pH) 4.0 - 4.4, 8.2 - 10.4, and the modifications to class 5 are to $feature_3$ (pH) 0.0 - 3.9, 10.5 - 14.0.

- In the context of industry. The criteria in classes 1, 2, 3, 4, and 5 are modified. The modifications to class 1 are to $feature_1$ (cond) 0.0 - 10.0, $feature_3$ (pH) 6.5 - 7.0, and $feature_5$ (tds) 0.0 - 99. The modifications to class 2 are to $feature_1$ (cond) 11 - 19, $feature_3$ (pH) 6.0 - 6.4, 7.1 - 7.2, and $feature_5$ (tds) 100 - 198. The modifications to class 3 are to $feature_1$ (cond) 20 - 245, $feature_3$ (pH) 4.5 - 5.9, 7.3 - 9.9, and $feature_5$ (tds) 199 - 1500. The modifications to class 4 are to $feature_1$ (cond) 246 - 1000, $feature_3$ (pH) 2.9 - 4.4, 10.0 - 11.9, and $feature_5$ (tds) 1501 - 7500, and the modifications to class 5 are to $feature_1$ (cond) more than 1001, $feature_3$ (pH) 0.0 - 2.8, 12.0 - 14.0, and $feature_5$ (tds) 7501 - 10000.

- In the context of irrigation. The criteria in classes 1, 2, and 3 are modified. The modifications to class 1 are to $feature_1$ (cond) 0 - 59, $feature_4$ (sal) 0.0 - 0.39, and $feature_5$ (tds) 0.0 - 349. The modifications to class 2 are to $feature_1$ (cond) 60 - 299, $feature_4$ (sal) 0.40 - 1.90, and $feature_5$ (tds) 350 - 1999, and the modifications to class 3 are to $feature_1$ (cond) 300 - 10000, $feature_4$ (sal) 2.0 - 15.0, and $feature_5$ (tds) 2000 - 10000.

1.3 The new criteria from the lesser part of the specialists' knowledge are shown in table 7.9 and the differences from the previous criteria are described as follows;

- In the context of irrigation. The criteria in classes 1, 2, and 3 are modified. The modifications to class 1 are to $feature_1$ (cond) 0 - 59, $feature_4$ (sal) 0.0 - 0.39, and $feature_5$ (tds) 0.0 - 349. The modifications to class 2 are to $feature_1$ (cond) 60 - 149, $feature_4$ (sal) 0.40 - 1.80, and $feature_5$ (tds) 350 - 1499, and the modifications to class 3 are to $feature_1$ (cond) 150 - 10000, $feature_4$ (sal) 1.9 - 15.0, and $feature_5$ (tds) 1500 - 10000.

Table 7.8 The feedback context based on specialist's knowledge in water-quality analysis field (B).

Context	Feature$_1$ (Cond)	Feature$_2$ (DO)	Feature$_3$ (pH)	Feature$_4$ (Sal)	Feature$_5$ (TDS)	Feature$_6$ (Turb)	Feature$_7$ (E. coli)	Feature$_8$ (Coliform bacteria)	Feature$_9$ (Enterococci)	Semantic meaning
Agriculture	0 – 29			0-0.14	0-149					Excellent for agriculture
	30 – 74			0.15-0.49	150-499					Hazard for sensitive crop
	75 – 300			0.5-2.5	500-2000					Hazard for low tolerance crop
	301 - 499			2.6-2.9	2001-3199					Hazard for high tolerance crop
	500-749			3.0-4.9	3200-5119					Satisfactory for livestock and poultry
	750-1999			5.0-6.9	5200-7039					Hazard for poultry
	2000-20000			7.0-30.0	7040-15000					Unfit for agriculture
	20001-50000			31.0-50.0	15001-20000					Suddenly toxic for agriculture
Aquatic life		7.1 -15.0								Abundant aquatic life
		6.0 – 7.0								Support growth and activity for aquatic life
		5.0 – 5.9								Support spawning
		3.0 – 4.9								Hazard for aquatic life
		0.0 – 2.9								All aquatic life extinction
Drinking			6.5-8.6		0-599	0-4.5				Optimum for drinking
			5.0-6.4, 8.7-9.5		600-1000	4.6-10.0				Hazard and chronic toxic for drinking
			0.0-4.9 9.6-14.0		> 1001	> 10.0				Unfit and toxic for drinking
Fish			7.1-8.1							Abundant for fish
			6.3-7.0							Optimum for fish and shrimp
			4.5-6.2							Bacteria and plankton being disappear
			4.0-4.4, 8.2-10.4							Hazard for fish and salmon dying
			0-3.9, 10.5-14.0							All fish extinction
Industry	0-10		6.5-7.0		0-99					Optimum for industrial process
	11-19		6.0-6.4, 7.1-7.2		100-198					Slightly corrosive scaling and fouling
	20-245		4.5-5.9, 7.3-9.9		199-1500					Moderate corrosive scaling and fouling
	249-1000		2.9-4.4, 10.0-11.9		1501-7500					Highly corrosive scaling and fouling
	> 1001		0.0-2.8, 12.0-14.0		7501-10000					Unfit for industrial process
Irrigation	0-59			0-0.39	0-349					Excellent for irrigation
	60-299			0.4-1.9	350-1999					Moderate hazard for irrigation
	300-10000			2.0-15.0	2000-10000					Hazard for irrigation
Recreation							0-100	0-500	0-40	Litter risk of illness
							101-1000	501-10000	41-400	Moderately risk of illness
							1001-10000	10001-100000	401-4000	Critical risk of illness
							10001-100000	100001-1000000	4001-40000	Strongly risk of illness
							100001-1000000	1000001-10000000	40001-100000	Excessively risk of illness

Table 7.9 The feedback context based on specialist's knowledge in water-quality analysis field (C).

Context	$Feature_1$ (Cond)	$Feature_2$ (DO)	$Feature_3$ (pH)	$Feature_4$ (Sal)	$Feature_5$ (TDS)	$Feature_6$ (Turb)	$Feature_7$ (E. coli)	$Feature_8$ (Coliform bacteria)	$Feature_9$ (Enterococci)	Semantic meaning
Agriculture	0 – 29			0-0.14	0-149					Excellent for agriculture
	30 – 300			0.15-2.5	150-2000					Hazard for sensitive crop
	301 – 399			2.6-2.7	2001-2499					Hazard for low tolerance crop
	400 - 499			2.8-2.9	2500-3199					Hazard for high tolerance crop
	500-749			3.0-4.9	3200-5119					Satisfactory for livestock and poultry
	750-1999			5.0-6.9	5200-7039					Hazard for poultry
	2000-15999			7.0-9.9	7040-10239					Unfit for agriculture
	16000-50000			10-50	10240-20000					Suddenly toxic for agriculture
Aquatic life		7.0 -15								Abundant aquatic life
		6.0 - 6.9								Support growth and activity for aquatic life
		5.0 – 5.9								Support spawning
		3.0 – 4.9								Hazard for aquatic life
		0.0 – 2.9								All aquatic life extinction
Drinking			6.5-8.4		0-199	0-1.9				Optimum for drinking
			5.0-6.4, 8.5-9.1		200-599	2.0-4.9				Hazard and chronic toxic for drinking
			0.0-4.9 9.2-14		600-1000	5.0-10.0				Unfit and toxic for drinking
Fish			6.5-8.1							Abundant for fish
			6.0-6.4							Optimum for fish and shrimp
			5-5.9							Bacteria and plankton being disappear
			4.0-4.9, 8.2-10.4							Hazard for fish and salmon dying
			0-3.9, 10.5-14.0							All fish extinction
Industry	0-29		6.5-7.9		0-199					Optimum for industrial process
	30-49		6.0-6.4, 8.0-8.9		200-349					Slightly corrosive scaling and fouling
	50-245		4.5-5.9, 9.0-9.9		350-1500					Moderate corrosive scaling and fouling
	246-1000		2.9-4.4, 10.0-11.9		1501-7500					Highly corrosive scaling and fouling
	1001-1200		0.0-2.8, 12.0-14.0		7501-10000					Unfit for industrial process
Irrigation	0-59			0-0.39	0-349					Excellent for irrigation
	60-149			0.4-1.8	350-1499					Moderate hazard for irrigation
	150-10000			1.9-15.0	1400-10000					Hazard for irrigation
Recreation							0-100	0-500	0-40	Litter risk of illness
							101-1000	501-10000	41-400	Moderately risk of illness
							1001-10000	10001-100000	401-4000	Critical risk of illness
							10001-80000	100001-1000000	4001-30000	Strongly risk of illness
							80001-1000000	1000001-10000000	30001-100000	Excessively risk of illness

1.4 Results of implementation of the specialists' knowledge (from the majority answering part) As a result of the implementation of the specialists' feedback from the majority to the least feedback are reflected in the contexts of agriculture, industry, and recreation, respectively. The analysis results were analyzed from the worst to best water-quality conditions for each context. The results of the implementation of the specialists' knowledge are summarized below;

- The results for water-quality with semantic-ordering functions for the context of agriculture based on the feedback from the specialists. From the results of the semantic ordering, the critical levels for health and hygiene impact attributable to water quality as suddenly toxic for agriculture were detected at Samut Phrakan 4 points and Bangkok 4 points. For the critical levels for health and hygiene impact attributable to water quality as unfit for agriculture were detected at Samut Phrakan 5 points, Nonthaburi 1 point, and Bangkok 1 point. The critical levels for health and hygiene impact attributable to water quality as hazardous for poultry were detected at Samut Phrakan 3 points, and Bangkok 2 points. The critical levels for health and hygiene impact attributable to water quality as satisfactory for livestock were detected at Samut Phrakan 1 points, Nonthaburi 2 points, and Bangkok 4 points. The critical levels for health and hygiene impact attributable to water quality as hazardous for high crops were detected at Bangkok 1 point, Phra Nakhon Si Ayutthaya 2 points. The results are shown in Figure 7.18. From Figure 7.18. in the first row to third row ranking it is seen that at Samut Prakan 2 points (February 17, 2014, and June 27, 2014) were suddenly toxic for agriculture. While the original result in the first to third ranking for Samut Prakan (June 27, 2013, February 17, 2014) showed to be suddenly toxic for agriculture. The original result is shown in Figure7.19. The significant ordering change is in order of 1-7, 10-23, 25-29, and 29-30. The significant semantic meaning change is in the order of 20 (satisfactory for livestock and poultry).

- The results of water quality with semantic-ordering functions for the context of industry based on feedback from the specialists. From the results of semantic ordering, the critical levels for health and hygiene impact attributable to water quality as unfit for industrial processes were detected at Samut Prakan 10 points, and Bangkok 4 points. For the levels for health and hygiene impact attributable to water quality as highly corrosive scaling and fouling were detected at Samut Prakan 3 points, Bangkok 7 points, and Nonthaburi 3 points. For the levels for health and hygiene impact attributable to water quality as moderate corrosive scaling and fouling were detected at Phra Nakhon Si Ayutthaya 1 point, and Bangkok 1 point. For the levels for health and hygiene impact attributable to water quality as slightly corrosive scaling and fouling were detected at Ang Thong 1 point etc. The result is shown in Figure 7.20. From the Figure 7.20 in the first row to third row ranking there are several points at Samut Prakan (February 13, 2013, February 17, 2014, and May 19, 2014) which showed as unfit for industrial processes. While the original result in the first row to third row ranking showed several points at Samut Prakan (February 17, 2014, May 19, 2013) as unfit for industrial processes. The original result is shown in Figure 7.21. The significant ordering change is in order of 1-2, 5-15, and 17-30. The significant semantic meaning change is in order of 15, 16, 18, 20, 21, 23, 25, 26, and 27 (unfit for industrial processes to highly corrosive scaling and fouling), and in order of 24 (moderate corrosive scaling and fouling to highly corrosive scaling and fouling).

- The results of water quality with semantic-ordering functions for the context of recreation based on the feedback of the specialists. From the results of the semantic ordering, the critical levels for health and hygiene impact attributable to water quality as critical risk of illness were detected at Nakhon Sawan 4 points, Samut Prakan 5 points, Nonthaburi 4 points, Chai Nat 2 points, Bangkok 13 points, Phra Nakhon Si Ayutthaya 1 point, and Sing Buri 1 point etc. The result is shown in Figure 7.22. From the Figure 7.22 in the first to third row ranking at Nakhon Sawan (July 28, 2012), Samut Prakan (August 19, 2013), and Nanthaburi (July 20, 2012), there was a critical risk of illness. While the original result in the first to third row ranking at Samut Prakan (June 27, 2013), Nakhon Sawan (August 13, 2013), and Chai Nat (February 21, 2013), there was a strong risk of illness. The original result is shown in Figure 7.23. The significant ordering change is in order of 1-22 and 24-30. For the significant semantic meaning change is in order of 5 and 6 (strongly risk of illness to critical risk of illness).

Part 2. The feedback result for water-quality (heavy metal parameter) criteria in each context from the specialist?s knowledge

As feedback on the water-quality (heavy metal parameter) criteria, the specialists evaluated the results for water quality between multiple water-quality (heavy

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ordering	semanticmeaning	factoragriculturea	conductivity	totaldissolvedsolid	salinity	ndate	location	latitude	longitude
1	Suddenly toxic for agriculture	4.516	36100	24187	23	2014-02-17	Samut Prakan	13.59696769	100.5943883
2	Suddenly toxic for agriculture	5.504	31100	20837	19.4	2014-02-17	Samut Prakan	13.65517619	100.5391245
3	Suddenly toxic for agriculture	6.643	28100	18827	16.8	2013-06-27	Samut Prakan	13.59696769	100.5943883
4	Suddenly toxic for agriculture	6.970	27300	18291	16.8	2014-02-17	Bangkok	13.70281824	100.5699897
5	Suddenly toxic for agriculture	8.097	25000	16750	15	2014-05-19	Samut Prakan	13.59696769	100.5943883
6	Suddenly toxic for agriculture	10.022	20900	14003	12.6	2014-02-17	Bangkok	13.69696996	100.494067
7	Suddenly toxic for agriculture	11.313	18200	12194	10.8	2013-06-27	Bangkok	13.70281824	100.5699897
8	Suddenly toxic for agriculture	11.784	17200	11524	10.2	2014-02-17	Bangkok	13.73626245	100.500363
9	Unfit for agriculture	13.467	16000	10720	9	2014-05-19	Samut Prakan	13.65517619	100.5391245
10	Unfit for agriculture	14.779	16000	10720	8	2013-02-18	Samut Prakan	13.59696769	100.5943883
11	Unfit for agriculture	16.783	20600	13802	2.3	2013-06-27	Samut Prakan	13.65517619	100.5391245
12	Unfit for agriculture	18.305	19000	12730	1.2	2012-12-17	Samut Prakan	13.59696769	100.5943883
13	Unfit for agriculture	19.461	18000	11193.9	1	2012-05-14	Samut Prakan	13.59696769	100.5943883
14	Unfit for agriculture	19.481	12200	8174	6.8	2014-02-17	Nonthaburi	13.81063373	100.5188004
15	Unfit for agriculture	20.721	12000	8040	7	2014-05-19	Bangkok	13.70281824	100.5699897
16	Hazard for poultry	25.059	10300	6901	5.7	2013-06-27	Bangkok	13.69696996	100.494067
17	Hazard for poultry	30.813	11000	6469.2	0.6	2012-05-14	Samut Prakan	13.65517619	100.5391245
18	Hazard for poultry	33.243	6900	4623	4	2013-02-18	Samut Prakan	13.65517619	100.5391245
19	Hazard for poultry	37.169	6900	4623	0.4	2012-12-17	Samut Prakan	13.65517619	100.5391245
20	Hazard for poultry	37.375	6350	4254.5	1.71	2013-06-27	Bangkok	13.73626245	100.500363
21	Satisfactory for livestock and poultry	41.661	4400	3099.4	0.2	2012-05-14	Bangkok	13.70281824	100.5699897
22	Satisfactory for livestock and poultry	42.346	2100	1407	0.1	2014-05-19	Bangkok	13.69696996	100.494067
23	Satisfactory for livestock and poultry	42.427	4360	2954.8	0.26	2012-02-13	Samut Prakan	13.59696769	100.5943883
24	Satisfactory for livestock and poultry	43.508	3520	2358.4	1.7	2013-06-27	Nonthaburi	13.81063373	100.5188004
25	Satisfactory for livestock and poultry	44.012	2820	1889.4	1.3	2014-02-18	Nonthaburi	13.94526881	100.5382517
26	Satisfactory for livestock and poultry	45.165	2200	1474	1	2013-02-18	Bangkok	13.70281824	100.5699897
27	Satisfactory for livestock and poultry	45.205	1900	1273	0.1	2012-12-17	Bangkok	13.70281824	100.5699897
28	Hazard for high tolerance crop	52.339	1100	737	0	2014-05-19	Bangkok	13.73626245	100.500363
29	Hazard for high tolerance crop	52.569	1070	716.9	0	2013-06-28	Phra Nakhon Si Ayutthaya	14.19189743	100.5595154
29	Hazard for high tolerance crop	52.569	1070	716.9	0	2013-06-28	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597

(stdin):

Fig. 7.18 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of agriculture (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).

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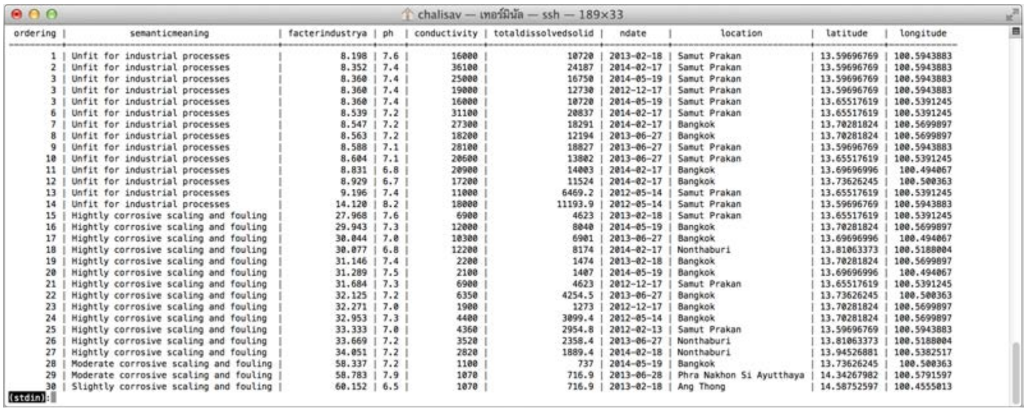
ordering	semanticmeaning	facteragriculture	conductivity	totaldissolvedsolid	salinity	ndate	location	latitude	longitude
1	Suddenly toxic for agriculture	1.592397423	28100	18827	16.8	2013-06-27	Samut Prakan	13.59696769	100.5943883
2	Suddenly toxic for agriculture	4.18779161	36100	24187	23	2014-02-17	Samut Prakan	13.59696769	100.5943883
3	Suddenly toxic for agriculture	6.239879954	31100	20837	19.4	2014-02-17	Samut Prakan	13.65517619	100.5391245
4	Suddenly toxic for agriculture	7.661276266	25000	16750	15	2014-05-19	Samut Prakan	13.59696769	100.5943883
5	Suddenly toxic for agriculture	7.785335758	27300	18291	16.8	2014-02-17	Bangkok	13.70281824	100.5699897
6	Suddenly toxic for agriculture	10.24767096	18200	12194	10.8	2013-06-27	Bangkok	13.70281824	100.5699897
7	Suddenly toxic for agriculture	10.36961482	20900	14003	12.6	2014-02-17	Bangkok	13.69696996	100.494067
8	Suddenly toxic for agriculture	11.86072878	17200	11524	10.2	2014-02-17	Bangkok	13.73626245	100.500363
9	Unfit for agriculture	13.42700155	16000	10720	9	2014-05-19	Samut Prakan	13.65517619	100.5391245
10	Unfit for agriculture	18.07989148	20600	13802	2.3	2013-06-27	Samut Prakan	13.65517619	100.5391245
11	Unfit for agriculture	19.43592091	19000	12730	1.2	2012-12-17	Samut Prakan	13.59696769	100.5943883
12	Unfit for agriculture	20.27124103	18000	11193.9	1	2012-05-14	Samut Prakan	13.59696769	100.5943883
13	Unfit for agriculture	20.44792969	12200	8174	6.8	2014-02-17	Nonthaburi	13.81063373	100.5188004
14	Unfit for agriculture	20.5812376	12000	8040	7	2014-05-19	Bangkok	13.70281824	100.5699897
15	Unfit for agriculture	24.39940744	16000	10720	8	2013-02-18	Samut Prakan	13.59696769	100.5943883
16	Unfit for agriculture	24.92154605	10300	6901	5.7	2013-06-27	Bangkok	13.69696996	100.494067
17	Hazard for poultry	31.99228516	11000	6469.2	0.6	2012-05-14	Samut Prakan	13.65517619	100.5391245
18	Hazard for poultry	33.15526961	6900	4623	4	2013-02-18	Samut Prakan	13.65517619	100.5391245
19	Hazard for poultry	36.03165391	6900	4623	0.4	2012-12-17	Samut Prakan	13.65517619	100.5391245
20	Satisfactory for livestock	37.85288173	6350	4254.5	1.71	2013-06-27	Bangkok	13.73626245	100.500363
21	Satisfactory for livestock	41.04903442	4400	3099.4	0.2	2012-05-14	Bangkok	13.70281824	100.5699897
22	Satisfactory for livestock	41.06574418	4360	2954.8	0.26	2012-02-13	Samut Prakan	13.59696769	100.5943883
23	Satisfactory for livestock	41.33490385	2820	1889.4	1.3	2014-02-18	Nonthaburi	13.94526881	100.5382517
24	Satisfactory for livestock	41.49001623	2100	1407	0.1	2014-05-19	Bangkok	13.69696996	100.494067
25	Satisfactory for livestock	42.18469806	3520	2358.4	1.7	2013-06-27	Nonthaburi	13.81063373	100.5188004
26	Satisfactory for livestock	44.29911844	1900	1273	0.1	2012-12-17	Bangkok	13.70281824	100.5699897
27	Satisfactory for livestock	44.83419349	2200	1474	1	2013-02-18	Bangkok	13.70281824	100.5699897
28	Hazard for high tolerance crop	52.00581865	1100	737	0	2014-05-19	Bangkok	13.73626245	100.500363
29	Hazard for high tolerance crop	52.06153148	1070	716.9	1.1	2012-12-19	Sing Buri	14.89606385	100.4054839
29	Hazard for high tolerance crop	52.06153148	1070	716.9	1.1	2013-06-29	Ang Thong	14.58752597	100.4555013

(stdin):

Fig. 7.19 The original results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of agriculture (Query: agriculture, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 8 conditions: Excellent for agriculture, Hazard for sensitive crop, Hazard for low tolerance crop, Hazard for high tolerance crop, Satisfactory for livestock and poultry, Hazard for poultry, Unfit for agriculture, and Suddenly toxic for agriculture)).



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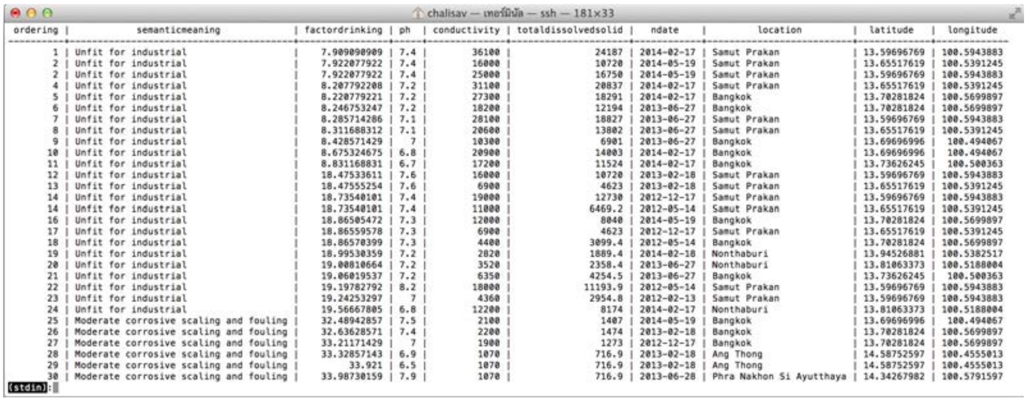
ordering	semanticmeaning	facterindustrya	ph	conductivity	totaldissolvedsolid	ndate	location	latitude	longitude
1	Unfit for industrial processes	8.198	7.6	16000	10720	2013-02-18	Samut Prakan	13.59696769	100.5943883
2	Unfit for industrial processes	8.352	7.4	36100	24187	2014-02-17	Samut Prakan	13.59696769	100.5943883
3	Unfit for industrial processes	8.360	7.4	25000	16750	2014-05-19	Samut Prakan	13.59696769	100.5943883
3	Unfit for industrial processes	8.360	7.4	19000	12730	2012-12-17	Samut Prakan	13.59696769	100.5943883
3	Unfit for industrial processes	8.360	7.4	16000	10720	2014-05-19	Samut Prakan	13.65517619	100.5391245
6	Unfit for industrial processes	8.539	7.2	31100	20837	2014-02-17	Samut Prakan	13.65517619	100.5391245
7	Unfit for industrial processes	8.547	7.2	27300	18291	2014-02-17	Bangkok	13.70281824	100.5699897
8	Unfit for industrial processes	8.563	7.2	18200	12194	2013-06-27	Bangkok	13.70281824	100.5699897
9	Unfit for industrial processes	8.588	7.1	28100	18827	2013-06-27	Samut Prakan	13.59696769	100.5943883
10	Unfit for industrial processes	8.604	7.1	20600	13802	2013-06-27	Samut Prakan	13.65517619	100.5391245
11	Unfit for industrial processes	8.831	6.8	20900	14003	2014-02-17	Bangkok	13.69696996	100.494067
12	Unfit for industrial processes	8.929	6.7	17200	11524	2014-02-17	Bangkok	13.73626245	100.500363
13	Unfit for industrial processes	9.196	7.4	11000	6469.2	2012-05-14	Samut Prakan	13.65517619	100.5391245
14	Unfit for industrial processes	14.120	8.2	18000	11193.9	2012-05-14	Samut Prakan	13.59696769	100.5943883
15	Hightly corrosive scaling and fouling	27.968	7.6	6900	4623	2013-02-18	Samut Prakan	13.65517619	100.5391245
16	Hightly corrosive scaling and fouling	29.943	7.3	12000	8040	2014-05-19	Bangkok	13.70281824	100.5699897
17	Hightly corrosive scaling and fouling	30.044	7.0	10300	6901	2013-06-27	Bangkok	13.69696996	100.494067
18	Hightly corrosive scaling and fouling	30.077	6.8	12200	8174	2014-02-17	Nonthaburi	13.81063373	100.5188004
19	Hightly corrosive scaling and fouling	31.146	7.4	2200	1474	2013-02-18	Bangkok	13.70281824	100.5699897
20	Hightly corrosive scaling and fouling	31.289	7.5	2100	1407	2014-05-19	Bangkok	13.69696996	100.494067
21	Hightly corrosive scaling and fouling	31.684	7.3	6900	4623	2012-12-17	Samut Prakan	13.65517619	100.5391245
22	Hightly corrosive scaling and fouling	32.125	7.2	6350	4254.5	2013-06-27	Bangkok	13.73626245	100.500363
23	Hightly corrosive scaling and fouling	32.271	7.0	1900	1273	2012-12-17	Bangkok	13.70281824	100.5699897
24	Hightly corrosive scaling and fouling	32.953	7.3	4400	3099.4	2012-05-14	Bangkok	13.70281824	100.5699897
25	Hightly corrosive scaling and fouling	33.333	7.0	4360	2954.8	2012-02-13	Samut Prakan	13.59696769	100.5943883
26	Hightly corrosive scaling and fouling	33.669	7.2	3520	2358.4	2013-06-27	Nonthaburi	13.81063373	100.5188004
27	Hightly corrosive scaling and fouling	34.051	7.2	2820	1889.4	2014-02-18	Nonthaburi	13.94526881	100.5382517
28	Moderate corrosive scaling and fouling	58.337	7.2	1100	737	2014-05-19	Bangkok	13.73626245	100.500363
29	Moderate corrosive scaling and fouling	58.783	7.9	1070	716.9	2013-06-28	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
30	Slightly corrosive scaling and fouling	60.152	6.5	1070	716.9	2013-02-18	Ang Thong	14.58752597	100.4555013

(stdin):

Fig. 7.20 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of industry (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).



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ordering	semanticmeaning	factordrinking	ph	conductivity	totaldissolvedsolid	ndate	location	latitude	longitude
1	Unfit for industrial	7.909090909	7.4	36100	24187	2014-02-17	Samut Prakan	13.59696769	100.5943883
2	Unfit for industrial	7.922077922	7.4	16000	10720	2014-05-19	Samut Prakan	13.65517619	100.5391245
2	Unfit for industrial	7.922077922	7.4	25000	16750	2014-05-19	Samut Prakan	13.59696769	100.5943883
4	Unfit for industrial	8.207792208	7.2	31100	20837	2014-02-17	Samut Prakan	13.65517619	100.5391245
5	Unfit for industrial	8.220779221	7.2	27300	18291	2014-02-17	Bangkok	13.70281824	100.5699897
6	Unfit for industrial	8.246753247	7.2	18200	12194	2013-06-27	Bangkok	13.70281824	100.5699897
7	Unfit for industrial	8.285714286	7.1	28100	18827	2013-06-27	Samut Prakan	13.59696769	100.5943883
8	Unfit for industrial	8.311688312	7.1	20600	13802	2013-06-27	Samut Prakan	13.65517619	100.5391245
9	Unfit for industrial	8.428571429	7	10300	6901	2013-06-27	Bangkok	13.69696996	100.494067
10	Unfit for industrial	8.675324675	6.8	20900	14003	2014-02-17	Bangkok	13.69696996	100.494067
11	Unfit for industrial	8.831168831	6.7	17200	11524	2014-02-17	Bangkok	13.73626245	100.500363
12	Unfit for industrial	18.47533611	7.6	16000	10720	2013-02-18	Samut Prakan	13.59696769	100.5943883
13	Unfit for industrial	18.47555254	7.6	6900	4623	2013-02-18	Samut Prakan	13.65517619	100.5391245
14	Unfit for industrial	18.73540101	7.4	19000	12730	2012-12-17	Samut Prakan	13.59696769	100.5943883
14	Unfit for industrial	18.73540101	7.4	11000	6469.2	2012-05-14	Samut Prakan	13.65517619	100.5391245
16	Unfit for industrial	18.86505472	7.3	12000	8040	2014-05-19	Bangkok	13.70281824	100.5699897
17	Unfit for industrial	18.86559578	7.3	6900	4623	2012-12-17	Samut Prakan	13.65517619	100.5391245
18	Unfit for industrial	18.86570399	7.3	4400	3099.4	2012-05-14	Bangkok	13.70281824	100.5699897
19	Unfit for industrial	18.99530359	7.2	2820	1889.4	2014-02-18	Nonthaburi	13.94526881	100.5382517
20	Unfit for industrial	19.00810664	7.2	3520	2358.4	2013-06-27	Nonthaburi	13.81063373	100.5188004
21	Unfit for industrial	19.06019537	7.2	6350	4254.5	2013-06-27	Bangkok	13.73626245	100.500363
22	Unfit for industrial	19.19782792	8.2	18000	11193.9	2012-05-14	Samut Prakan	13.59696769	100.5943883
23	Unfit for industrial	19.24253297	7	4360	2954.8	2012-02-13	Samut Prakan	13.59696769	100.5943883
24	Unfit for industrial	19.56667805	6.8	12200	8174	2014-02-17	Nonthaburi	13.81063373	100.5188004
25	Moderate corrosive scaling and fouling	32.48942857	7.5	2100	1407	2014-05-19	Bangkok	13.69696996	100.494067
26	Moderate corrosive scaling and fouling	32.63628571	7.4	2200	1474	2013-02-18	Bangkok	13.70281824	100.5699897
27	Moderate corrosive scaling and fouling	33.21171429	7	1900	1273	2012-12-17	Bangkok	13.70281824	100.5699897
28	Moderate corrosive scaling and fouling	33.32857143	6.9	1070	716.9	2013-02-18	Ang Thong	14.58752597	100.4555013
29	Moderate corrosive scaling and fouling	33.921	6.5	1070	716.9	2013-02-18	Ang Thong	14.58752597	100.4555013
30	Moderate corrosive scaling and fouling	33.98730159	7.9	1070	716.9	2013-06-28	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597

(stdin):

Fig. 7.21 The original results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of industry (Query: industry, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Optimum for industrial process, Slightly corrosive scaling and fouling, Moderate corrosive scaling and fouling, Highly corrosive scaling and fouling, and Unfit for industrial process)).

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ordering	semanticmeaning	factorrecreation	e_coli	coliformbacteria	ndate	location	latitude	longitude
1	Critical risk of illness	65.510	11000	79000	2012-07-08	Nakhon Sawan	15.68576833	100.1261431
1	Critical risk of illness	65.510	13000	79000	2013-08-19	Samut Prakan	13.59696769	100.5943883
3	Critical risk of illness	65.891	17000	75000	2012-07-20	Nonthaburi	13.81063373	100.5188004
3	Critical risk of illness	65.891	17000	75000	2014-05-19	Nonthaburi	13.81063373	100.5188004
5	Critical risk of illness	66.778	28000	132000	2013-08-13	Nakhon Sawan	15.68576833	100.1261431
6	Critical risk of illness	67.067	54000	106000	2013-02-21	Chai Nat	15.18068386	100.1244463
7	Critical risk of illness	67.606	35000	57000	2013-02-18	Bangkok	13.70281824	100.5699897
8	Critical risk of illness	68.939	11000	43000	2013-06-27	Nonthaburi	13.81063373	100.5188004
9	Critical risk of illness	69.129	13000	41000	2013-08-19	Bangkok	13.73626245	100.500363
9	Critical risk of illness	69.129	13000	41000	2012-07-20	Bangkok	13.73626245	100.500363
11	Critical risk of illness	69.225	50000	40000	2014-05-19	Chai Nat	15.42268813	100.138766
12	Critical risk of illness	69.510	17000	37000	2012-02-13	Bangkok	13.73626245	100.500363
13	Critical risk of illness	69.951	14000	7000	2012-02-13	Bangkok	13.69696996	100.494067
14	Critical risk of illness	70.558	28000	26000	2012-07-20	Samut Prakan	13.65517619	100.5391245
15	Critical risk of illness	70.709	4000	88000	2012-07-20	Bangkok	13.69696996	100.494067
16	Critical risk of illness	70.748	11000	24000	2013-08-19	Bangkok	13.69696996	100.494067
17	Critical risk of illness	70.939	13000	22000	2013-06-27	Samut Prakan	13.59696769	100.5943883
18	Critical risk of illness	71.142	7900	84100	2013-06-27	Bangkok	13.69696996	100.494067
18	Critical risk of illness	71.142	7900	84100	2014-05-19	Bangkok	13.70281824	100.5699897
20	Critical risk of illness	71.225	35000	19000	2014-05-19	Bangkok	13.73626245	100.500363
21	Critical risk of illness	71.320	17000	18000	2014-02-17	Nonthaburi	13.81063373	100.5188004
21	Critical risk of illness	71.320	17000	18000	2013-02-19	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
21	Critical risk of illness	71.320	17000	18000	2012-12-17	Bangkok	13.73626245	100.500363
24	Critical risk of illness	71.796	17000	13000	2014-05-19	Nakhon Sawan	15.68576833	100.1261431
25	Critical risk of illness	71.939	1700	158300	2012-07-23	Sing Buri	15.01212969	100.3307434
26	Critical risk of illness	71.977	4700	155300	2012-07-20	Bangkok	13.70281824	100.5699897
27	Critical risk of illness	71.987	24000	11000	2012-07-20	Samut Prakan	13.59696769	100.5943883
27	Critical risk of illness	71.987	24000	11000	2013-08-19	Samut Prakan	13.65517619	100.5391245
29	Critical risk of illness	72.914	22000	0	2014-02-17	Bangkok	13.70281824	100.5699897
29	Critical risk of illness	72.914	30000	0	2012-11-05	Nakhon Sawan	15.68576833	100.1261431

(stdin):

Fig. 7.22 The results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of recreation (Query: recreation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Little risk of illness, Moderately risk of illness, Critical risk of illness, Strongly risk of illness, and Excessively risk of illness)).

chalisav — เทอร์มินัล — ssh — 158×33

ordering	semanticmeaning	factorrecreation	e_coli	coliformbacteria	ndate	location	latitude	longitude
1	Strongly risk of illness	57.23791067	92000	68000	2013-06-27	Samut Prakan	13.65517619	100.5391245
2	Strongly risk of illness	57.8875969	28000	132000	2013-08-13	Nakhon Sawan	15.68576833	100.1261431
3	Strongly risk of illness	59.28294574	54000	106000	2013-02-21	Chai Nat	15.18068386	100.1244463
4	Critical risk of illness	62.5092285	50000	40000	2014-05-19	Chai Nat	15.42268813	100.138766
5	Critical risk of illness	62.52307124	35000	57000	2013-02-18	Bangkok	13.70281824	100.5699897
6	Critical risk of illness	62.7057955	17000	75000	2014-05-19	Nonthaburi	13.81063373	100.5188004
6	Critical risk of illness	62.7057955	17000	75000	2012-07-20	Nonthaburi	13.81063373	100.5188004
8	Critical risk of illness	62.74640089	13000	79000	2013-08-19	Samut Prakan	13.59696769	100.5943883
9	Critical risk of illness	62.90513104	11000	79000	2012-07-08	Nakhon Sawan	15.68576833	100.1261431
10	Critical risk of illness	63.13999631	7900	152100	2012-05-14	Bangkok	13.69696996	100.494067
11	Critical risk of illness	64.11175711	7900	84100	2014-05-19	Bangkok	13.70281824	100.5699897
11	Critical risk of illness	64.11175711	7900	84100	2013-06-27	Bangkok	13.69696996	100.494067
13	Critical risk of illness	65.01522702	4700	155300	2012-07-20	Bangkok	13.70281824	100.5699897
14	Critical risk of illness	65.15319306	35000	19000	2014-05-19	Bangkok	13.73626245	100.500363
15	Critical risk of illness	65.22425249	28000	26000	2012-07-20	Samut Prakan	13.65517619	100.5391245
16	Critical risk of illness	65.33591731	17000	37000	2012-02-13	Bangkok	13.73626245	100.500363
17	Critical risk of illness	65.3765227	13000	41000	2013-08-19	Bangkok	13.73626245	100.500363
17	Critical risk of illness	65.3765227	13000	41000	2012-07-20	Bangkok	13.73626245	100.500363
19	Critical risk of illness	65.3968254	11000	43000	2013-06-27	Nonthaburi	13.81063373	100.5188004
20	Critical risk of illness	66.05297158	4000	88000	2012-07-20	Bangkok	13.69696996	100.494067
21	Critical risk of illness	66.57991879	24000	11000	2012-07-20	Samut Prakan	13.59696769	100.5943883
21	Critical risk of illness	66.57991879	24000	11000	2013-08-19	Samut Prakan	13.65517619	100.5391245
23	Critical risk of illness	66.65097822	17000	18000	2012-12-17	Bangkok	13.73626245	100.500363
23	Critical risk of illness	66.65097822	17000	18000	2014-02-17	Nonthaburi	13.81063373	100.5188004
23	Critical risk of illness	66.65097822	17000	18000	2013-02-19	Phra Nakhon Si Ayutthaya	14.34267982	100.5791597
26	Critical risk of illness	66.69158361	13000	22000	2013-06-27	Samut Prakan	13.59696769	100.5943883
27	Critical risk of illness	66.7118863	11000	24000	2013-08-19	Bangkok	13.69696996	100.494067
28	Critical risk of illness	66.77325581	1700	158300	2012-07-23	Sing Buri	15.01212969	100.3307434
29	Critical risk of illness	66.99704688	17000	13000	2014-05-19	Nakhon Sawan	15.68576833	100.1261431
30	Critical risk of illness	67.10535778	14000	7000	2012-02-13	Bangkok	13.69696996	100.494067

(stdin):

Fig. 7.23 The original results of the water-quality analysis system with semantic-ordering functions on multiple parameters for local analysis in the context of recreation (Query: recreation, Semantic ordering: levels of health and hygiene impact attributable to water quality (ordering by using 5 conditions: Little risk of illness, Moderately risk of illness, Critical risk of illness, Strongly risk of illness, and Excessively risk of illness)).

metal) parameters and the semantic meaning in each context. The results of the implementation of feedback from the specialists are summarized as follows;

- In the context of aquatic life: Arsenic is less than 10 μg/L, Cadmium is less than 1 μg/L, Chromium is less than 1 μg/L, Copper is less than 4 mg/L, Iron is less than 300 mg/L, Lead is less than 7 mg/L, Mercury is less than 0.003 μg/L, Nickel is less than 25 μg/L, and Zinc is less than 5 mg/L, the specialists evaluated the results of water quality as "safe for aquatic life" 71.43 percent (same condition as the criteria in this study), and "threshold toxic for aquatic life" 28.57 percent.

- In the context of livestock and wildlife. In the condition: Arsenic is 30 μg/L, Cadmium is 50 μg/L, Chromium is less than 1000 μg/L, Copper is less than 1000 mg/L, Iron is less than 100 mg/L, Lead is less than 50 mg/L, and Mercury is less than 1 μg/L, the specialists evaluated the results of water quality as "satisfactory for Livestock and Wildlife" 42.86 percent (same condition as the criteria in this study), and "threshold toxic for Livestock and Wildlife" 57.14 percent.

- In the context of irrigation. In the condition: Arsenic is 1000 μg/L, Cadmium is 1000 μg/L, Chromium is 150 μg/L, Copper is 400 mg/L, Iron is 300 mg/L, Lead is 6000 mg/L, Mercury is 5 μg/L, Nickel is 500 μg/L, and Zinc is 5000 mg/L, the specialists evaluated the results of water-quality as "excellent" 14.29 percent, and "threshold toxic for Livestock and Wildlife" 85.71 percent (same condition as the criteria in this study).

- In the context of industry. In the condition: Arsenic is 250 μg/L, Cadmium is 1000 μg/L, Chromium is 5000 μg/L, Copper is 4000 mg/L, Iron is 3000 mg/L, Lead is 600 mg/L, and Mercury is 10 μg/L, the specialists evaluate the results of water quality is in "optimum for industrial process" 14.29 percent, and "Until, high corrosive and fouling for industrial process" 85.71 percent (same condition as the criteria in this study).

- In the context of estuary basic water. In the condition: Arsenic is 200 μg/L, Cadmium is 3 μg/L, Chromium is 120 μg/L, Copper is 300 mg/L, Iron is 300 mg/L, Lead is 200 mg/L, Mercury is 0.1 μg/L, Nickel is 100 μg/L, and Zinc is 5000 mg/L, the specialists evaluated the results of water quality as "optimum for Estuary Basic Water" 50.00 percent, and "Damage for Estuary Basic Water" 50.00 percent (same condition as the criteria in this study).

Part 3. The rating feedback for the water-quality result

As the rating feedback results for water-quality, the specialists evaluated the results of water quality between multiple water-quality parameters and semantic meaning with agree and disagree. The results of the rating feedback to reflect/feedback specialists' knowledge are summarized as

- In the context of agriculture, the specialists evaluate the results of water-quality with agree 92.86 percent and disagree 7.14 percent.
- In the context of aquatic life, the specialists evaluate the results of water-quality with agree 64.29 percent and disagree 35.71 percent.
- In the context of drinking, the specialists evaluate the results of water-quality with agree 92.86 percent and disagree 7.14 percent.
- In the context of industry, the specialists evaluate the results of water-quality with agree 92.86 percent and disagree 7.14 percent.
- In the context of irrigation, the specialists evaluate the results of water-quality with agree 100 percent.

Part 4. The result of feedback suggestion for improvement system

From the result of feedback suggestion for improvement system consists of 3 parts as below
1) The parameters and meanings should be considered in the future to improve system more precise in context of agriculture, aquatic life, fish, drinking, industry, irrigation, recreation, and heavy metal.

- Color, persistent organic contaminates, viruses, and manganese
- Emerging organic pollutants
- Heavy metal parameter in drinking context
- Odor
- Biological Oxygen Demand (BOD)
- Nitrate
- Sulfate
- Chemical Oxygen Demand (COD)

- Pesticide
- Any compound causes health risk
- Some concerned trace elements and nutrient (N and P)

2) The context should be added for aquatic context system in the future study

- Context of aquatic vegetation
- Standard of water reuse for agriculture, industries, domestic area

3) The other suggestion recommendation to develop the system

- Degree of toxicity depends on both concentration and exposure duration
- The range of each parameter is too wide and too many choices (class)
- Wastewater context may study for the future

The results of the mechanism to reflect specialists' knowledge in detail shown in Appendix B.

7.3.3 Conclusion

The new water-quality criteria in this study were established by considering international standard criteria of the World Health Organization, Canadian Council of the Environment Ministry, United States Environmental Protection Agent, Food and Agriculture organization, Ministry of Natural Resource and Environment (Thailand), Health and Ecological Criteria Division (UN-EPA) [33-35, 37, 39, 52], and the scientific journals [7-9, 40, 41, 43-46, 47-49, 53]. For the development, this process presents the mechanism of application of the specialists' knowledge. The new criteria from the majority answering part of the mechanism to reflect the specialists' knowledge in the system is in the contexts of agriculture, industry, and recreation. For the feedback result for water-quality (heavy metal parameter) criteria in each context from the specialist's knowledge, the specialists evaluated the results of water quality in the same definition as the current criteria 71.43 percent (in the condition of aquatic life context), 35.71 percent (in the context of livestock and wildlife), 85.71 percent (in the context of irrigation and industry), and 50 percent (in the context of estuary basic water). The rating feedback of the water-quality result as accepted is 64.29 - 92.86 percent for the water quality analysis system. The result showed that it is more significant to develop dynamic analysis changes and also to use wider ranges in some classes which define the semantic meaning in lower levels more than the standard and scientific statements. By all means, the analytical meaning still covers the practical system meaning but in some definitions the system might not cope with some meanings for in depth analysis.

Some of the limitations from the questionnaire and specialist feedback in the water-quality parameters tend to be in terms of the same opinion. There are the answering choices and semantic word meanings, which are complicated for specialists' evaluation. Because of (1) the answering choices are based on scientific international standard information and journals, and (2) water-quality parameters based on subspace selection according to contexts (MMM concept), which are used in the number of classifications for this dissertation. For in depth analysis and water quality interpretation, the number of water-quality parameters and answering choices must be given by the semantically meaningful words.

For system development in the further work, the parameters of color, persistent organic contaminates, viruses, manganese, emerging organic pollutants, heavy metal parameter (in the drinking context), odor, biological oxygen demand (BOD), nitrate, sulfate, chemical oxygen demand (COD), pesticides, any compound which causes health risk, some concerning trace elements and nutrients (N and P) could be considered for inclusion into the system. Moreover, the context of aquatic vegetation and wastewater could be also added into the system to gaining a more dynamic and flexible analysis.

Chapter 8

Future Application

8.1 Future Application

Defining the semantic analysis for explaining environment conditions, especially water-quality, is one of the new ways to realize environmental conditions in human language interpretation technology. Therefore, we strongly believe this idea and the proposed methods are a new innovation and starting point in the field of semantic computing in water-quality analysis and will become the essential tool for the preservation of the environments. While this dissertation has demonstrated the potential of efficiently analyzing of water-quality by applying semantic computing in MMM, many opportunities for extending the scope of this dissertation remained. This chapter presents some of these directions.

8.1.1 To extend the proposed method

We are going to extend the proposed method in this dissertation in processing and actuation by adding specific functions for water-quality analysis and classification. For instance,

- The semantic water-quality portal which supports water pollution identification.
- The semantic correlation between contaminants and health impacts, which investigates and supports both non-expert and expert users in water-quality monitoring.

8.1.2 To extend to the other domain

Regarding the application of water-quality analysis with semantic computing to the other domain for making progress in an Environmental AI, an extension for the near future is usefulness and promising for Environmental Engineering and Scientist. These future works are valuable for researchers in Environmental Engineering and Scientist and they can guide researchers to new researcher directions and core ideas in Environmental AI. So we are going to make progress in an Environmental AI by extending to the other domains in order to (1) to provide a core idea for future direction on Environmental analysis, (2) to facilitate research for reducing the complex research's task, and (3) to make a big integration of various professional's knowledge resources of the experts on Environmental analysis. A possibility of the semantic computing to Environmental AI is presented in this dissertation as a water-quality analysis with multi-dimensional space, which based on the deep professional knowledge in the water-quality field and semantic computing from MMM and expresses the professional's knowledge in a systematic way as a multi-dimensional space. In this dissertation implemented from 2 cores ideas as (1) a professional knowledge finding and (2) mapped professional knowledge into dimensional. The core ideas of this study are able to apply to the other environmental domains because this method is practicable to analyze the numerical data, which can be measured from the sensing device. This study presents the possibility to utilize the natural resources data from the nature and interpret the meaning of environmental situation by analyzing the important parameters to the meaningful words. Thus, this method is applicable to analyze the other environmental domains such as soil condition, air pollution, and solid waste management which the sensing devices can be collected the numerical data same as water sensor, then apply semantic computing concept to interpret the actual situations. The other important point for utilizing this method is to obtain the professional knowledge in each specific field to the analysis system, which can be improved the precision and accuracy of the system and users can acquire the professional-interpreting results. Moreover, this system can integrate multimedia data such as image data, texts data, and audio, which acquired from sensing devices to analyze the environmental situation and interpret the meaningful words more sharply. The system Architecture of the future work is shown in Figure 8.1

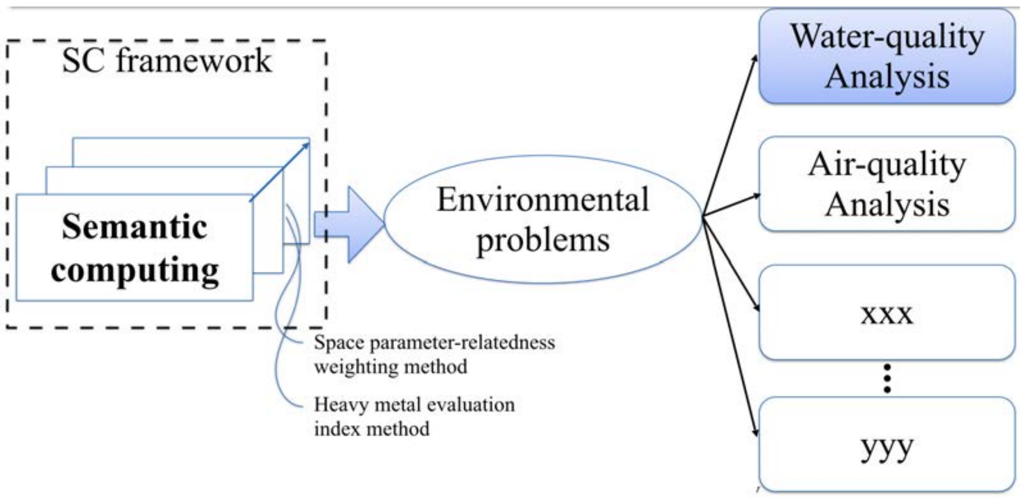

Fig. 8.1 The process to define water-quality meaning and map to multi-dimensional semantic space

The newly constructed innovation from numeric to human language plays a dramatic part in the environmental issues of today. The development of this system in the future looks toward an accuracy specific functional integration with an algorithm for adding more information from other fields of environment impact phenomena.

Chapter 9

Concluding remarks

9.1 Conclusion

This dissertation proposed an automatic system of water quality analysis in different contexts of dynamic subspace selection according to context. The proposed method addressed in 3 significant advantage points that have not been solved by previous research: (1) river-water-quality comparison in the global scale and broader water-quality analysis. (2) Extracting water-quality features in different views and in dynamic sub-space selection in contexts. (3) Interpretation of water-quality by transforming the sensor value-information to the language-information for making the results more understandable to public users in the feature semantic wording. Furthermore, this dissertation is established a professional knowledge level database in the water-quality analysis and the world water-quality notification system for discovering the critical points from multiple areas and timelines. By all means, the river water-quality analysis system can be a tangible tool for assessment on the worldwide scale and several main targets for public users.
In chapter 1: this dissertation outlines the water-quality definitions, objective, problem, research challenges, and expected results of this thesis. Firstly, it introduces the definition of an important water parameter in part of physical, chemical, and biological characteristics. Secondly, it describes dissertation's objective and problems, which focus on the limitation of existing implementation in water quality analysis. Thirdly, it describes the research challenges and expected results, which are the way for solving a limit points in previous research.
In chapter 2: this dissertation refers to related works. The literature review in the dissertation is related to environmental analysis and semantic computing. The dissertation refers to not only water-quality analysis in several methods in water resource assessment but also refer to the semantic computing and data

visualization. These are conceptualized for finding the new framework theoretical analysis.

In chapter 3: this dissertation introduces an innovative approach for river water-quality analysis system. This approach provides a feasible and effective system to analyze water-quality and integration procedure, which is extremely important in water-quality analysis system for public users. Firstly, it introduces rSPA process as an effective tools for data analysis and visualization in global areas. Secondly, it describes the productivity approach for critical detection classification and real-time warning system, which are an important aspect of designing environmental systems. Thirdly, it describes the approach for interpreting Environmental Situations by a multi-dimensional semantic space, which is a promising approach to a new interpreting of environments by the sensing value information and the language information on intellectual activities into various environment meanings to society. Fourthly, it describes the analysis method of water quality, depending on the type of data samples, type of target groups, the size of the samples and information goals, and creating the index from the dimensional subspace in the heavy metal parameter for determining the quality of water resources. This index is one of the effective ways to present the results of the estimation-related environmental situation by several parameters or attributes. Fifthly, it describes the approach for making progress on multi-dimensional semantic space by creating semantic-ordering functions for water quality analyzed in wide areas.

In chapter 4: this dissertation describes an implementation of the system design, overview of the system architecture in water-quality analysis system with multi-dimensional spaces for interpreting environmental situations. The implementation consists of system design and data structure. For system design has 3 parts: (1) sensing part. (2) processing and analyzing part. (3) actuation and output part. There are 2 data structures: (1) data structure on 5D World Map system, which is held water-quality data with semantic and spatiotemporal metadata in the separate file. (2) data structure on the database for semantic space, which is stored of water-quality data for semantic space creation and analysis.

In chapter 5: this dissertation describes the process of data preparation, which is required for the system operation. There is 2 types of data were collected: (1) an observation data, which is data from our sensor and data from the national sensor. (2) an open data, which is data from national institute collection, metadata, and requested data. Those of data are specific to the environmental situations. The environmental change, therefore those data was collected with several areas and thoroughly process accuracy data purposes.

In chapter 6: this dissertation describes analysis results of the procedure in proposed methods. From an analysis result in this proposed methods are clarified the limitation of the previous implementation. The analysis result consists of (1) to analyze and visualize the water-quality with 5D World Map System, water-quality index, and metal index. (2) To analyze by using the river Sensing Processing Actuation processes (rSPA), which is determined and classified in multiple-water parameters. (3) To analyze by using the multi-dimensional semantic space. (4) To analyze by using the river Heavy Metal Evaluation Index (rHMEI), dimensional semantic space. (5) To analyze by using the semantic-ordering function, and (6) To integrate between parameter relatedness weightless method and rHMEI in an industry context, which is effective than the other method because of it flexible for different types of dose response function, different unit of features, and the different kind of indicator.

In chapter 7: this dissertation describes the evaluation environment process and result. From the specialists' evaluation in the water-quality analysis, the classification and analysis result are acceptable in positively. Moreover, the comparison of accuracy assessment results from with the other water quality standard is presented that this approach is suitable to apply to the diverse-study areas. Particularly, the analysis method provides both equal and high precision in comparison with the international standard criteria. In addition, the result of the mechanism system are reflected the specialists' knowledge shows the possibility to develop the system more attainable in local sector analysis with the wider range level, while the interpreting results are quite different from the international standard and scientific statement (in some class), which might not be able to use in deep analysis.

In chapter 8: this dissertation describes a new unique approach for future application, which is addressed to improve and expand our proposed method by extending the system.

In chapter 9: this dissertation provides a brief overview of this thesis in each chapter and contribution in research areas.

9.2 Contribution

This research study proposed the automatic system for water-quality analysis using several databases and different contexts in dynamic sub-space selection according to contexts. This system is the new approach of water-quality interpretation to lead the water-quality analysis field by transforming from the sensor-value-information to the language-information, which is a useful way to understand the water situation and highly effective to the global water-quality analysis and assessment. The feature of this research are given by effective tools as below:

- System applications for the water-quality analysis of rivers all over the world (World river water-quality reporting system)
- Integration of various professional knowledge resources and the experts on water-quality analysis
- Memory recall of water-quality situations from all over the world, which is related to any interests expressed in language
- An automatic human-interpretation system by integrating knowledge of environmental engineering and semantic computing.
- A proposed dynamic-dimensions for river-water-quality interpretation for making the system high potential, analyzing all the independent aspects
- A proposed semantic space parameter-relatedness weighting method of river-water-quality variability and river Heavy Metal Evaluation Index (rHMEI)

Our system and analysis with implementation studies are highly significant to societies and those research results can be broadly used in data-analysis, observations and visualizations in the water-quality resource issues.

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Appendix A

The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis in each context

Part I. Agriculture context

Part II. Aquatic life context

Part III. Fish context

Part IV. Drinking context

Part V. Industry context

Part VI. Irrigation context

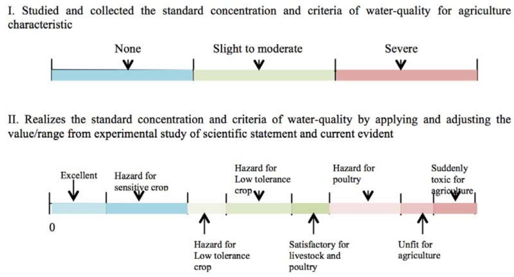


Fig. A.1 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the agriculture context

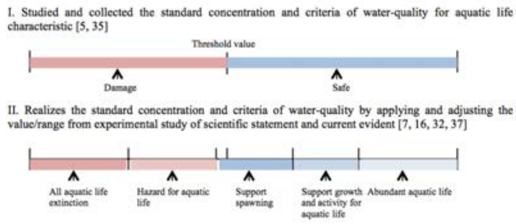


Fig. A.2 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the aquatic life context

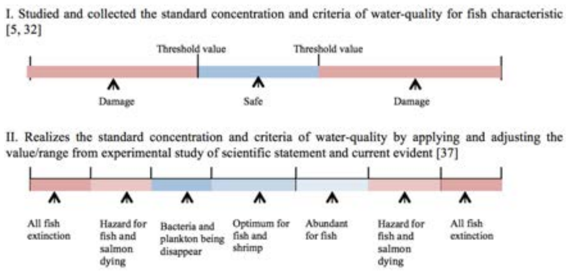


Fig. A.3 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the fish context

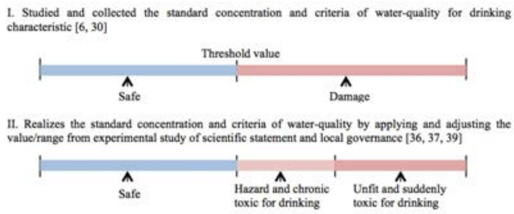


Fig. A.4 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the drinking context

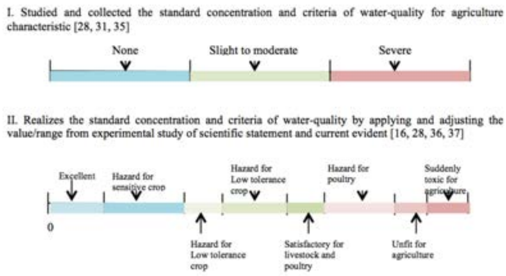


Fig. A.5 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the industry context

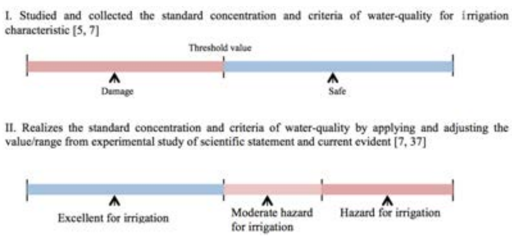


Fig. A.6 The example for the strategy and process to establish the new knowledge representation of the professional's knowledge in water-quality analysis for the irrigation context

Appendix B

Mechanism to reflect/feedback specialists' knowledge

Part I. Physical, Chemical, and Biological parameters

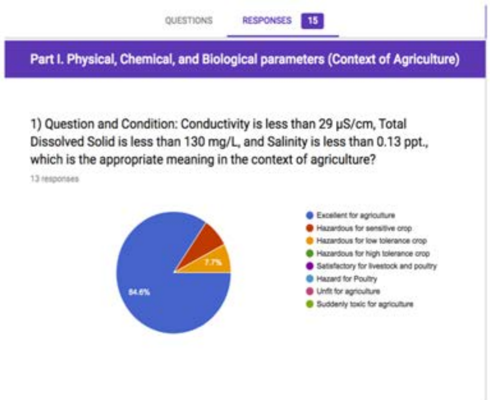
- Context Agriculture
- Context Aquatic life
- Context Drinking
- Context Fish
- Context Industry
- Context Irrigation
- Context Recreation

Part I. Heavy metal parameters

- Context Aquatic life
- Context Livestock and Wildlife
- Context Industry
- Context Irrigation
- Context Estuary Basic Water

Part III. Rating the results of water-quality

Part IV. Suggestion and Feedback



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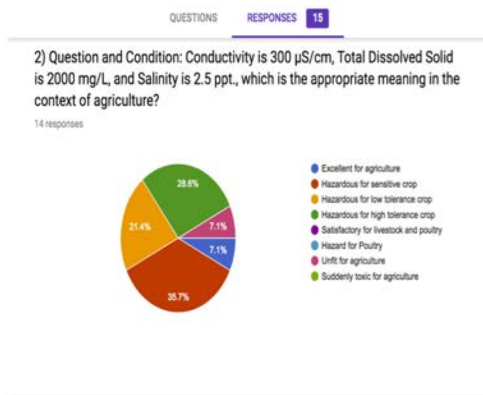

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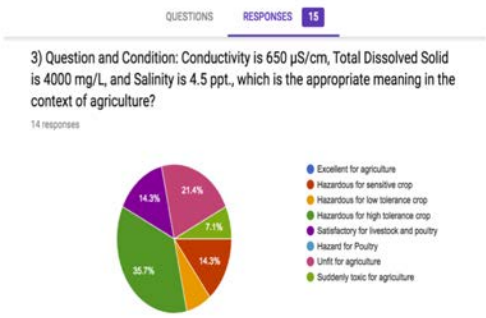

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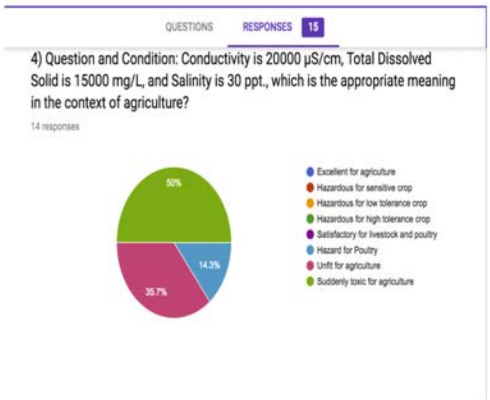
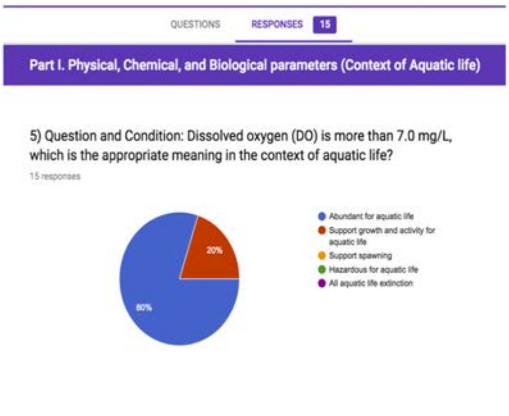


(Question 4)

Fig. B.1 Part I. Physical, Chemical, and Biological parameters in Context of Agriculture



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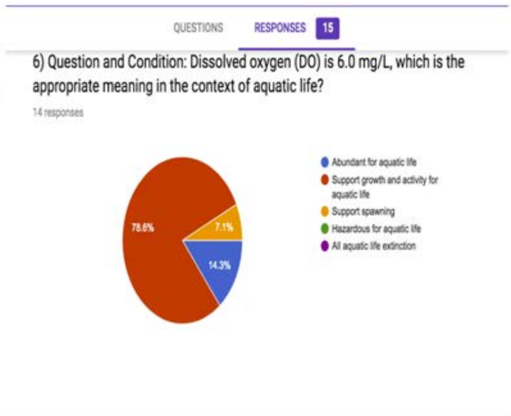

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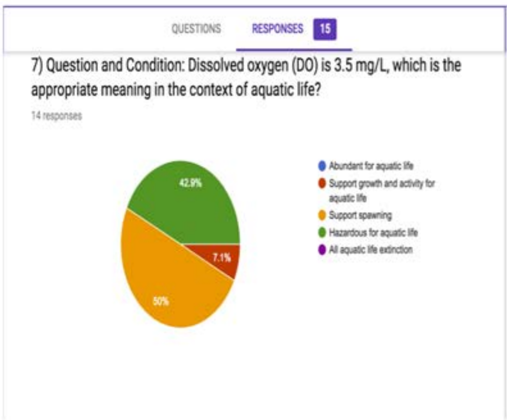

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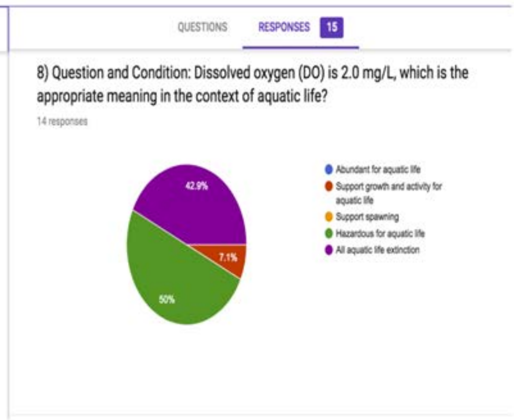
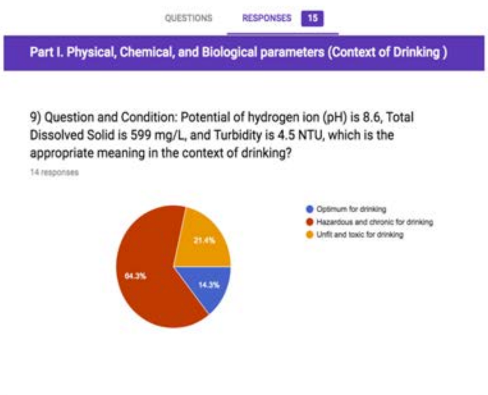


(Question 8)

Fig. B.2 Part I. Physical, Chemical, and Biological parameters in Context of Aquatic life



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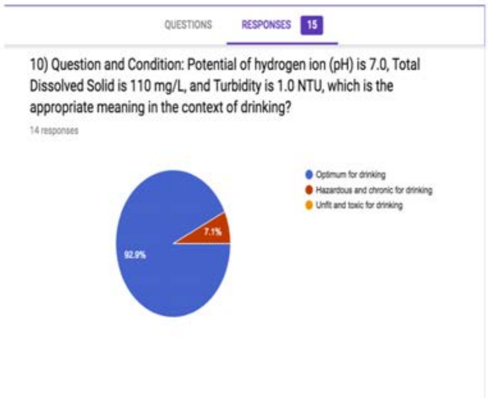

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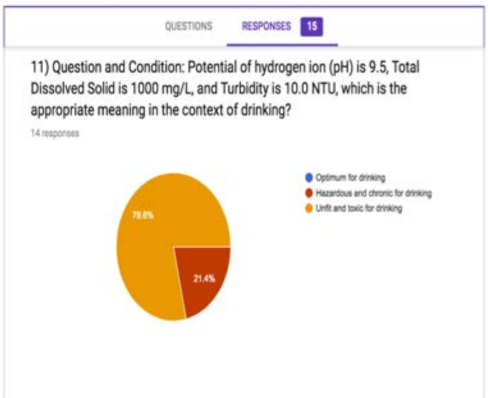
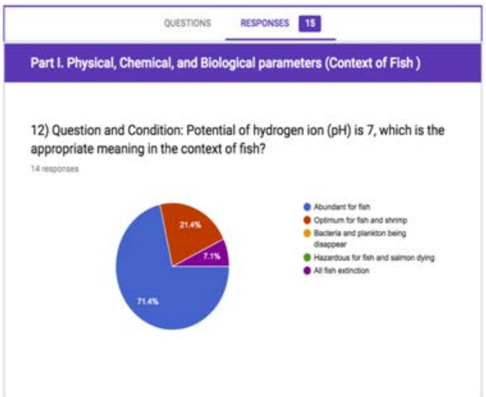


(Question 11)

Fig. B.3 Part I. Physical, Chemical, and Biological parameters in Context of Drinking



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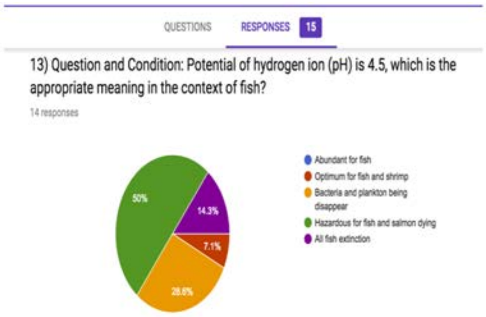

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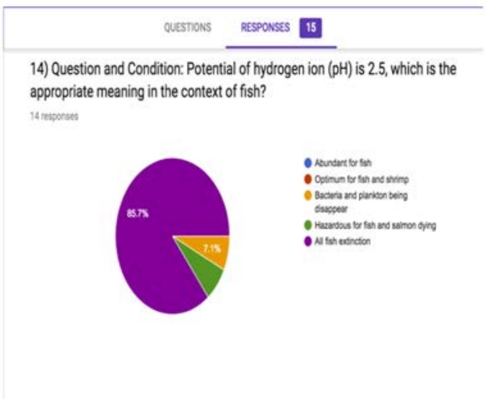

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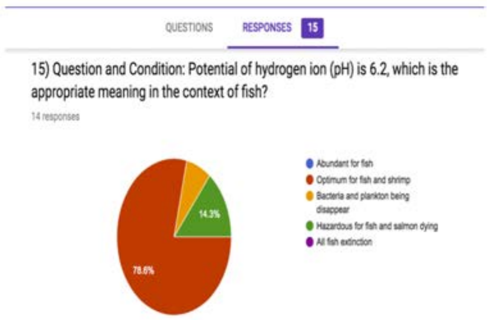
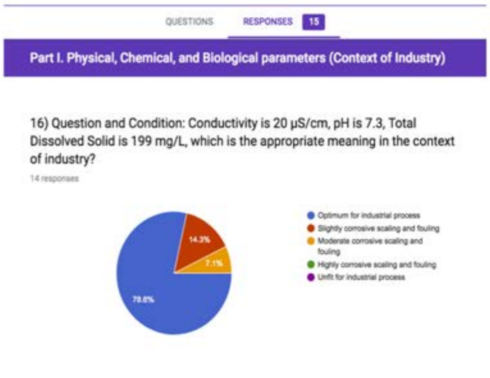


(Question 15)

Fig. B.4 Part I. Physical, Chemical, and Biological parameters in Context of Fish



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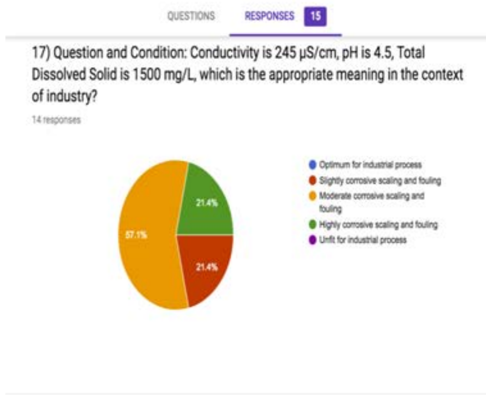

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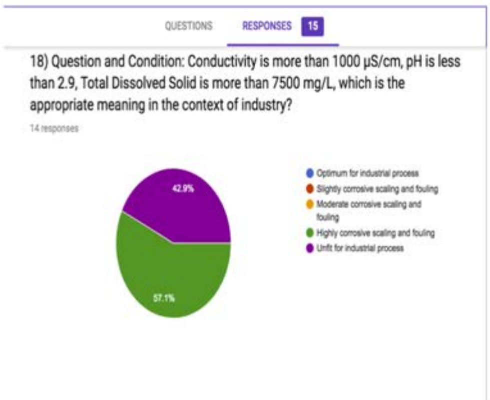

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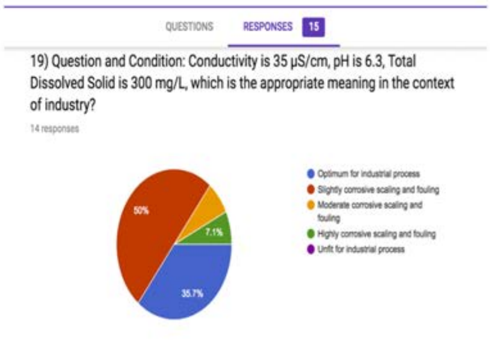

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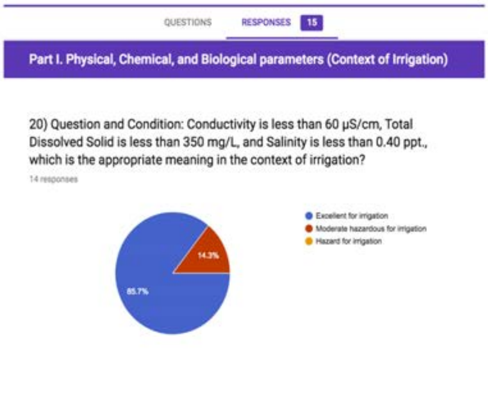
Fig. B.5 Part I. Physical, Chemical, and Biological parameters in Context of Industry



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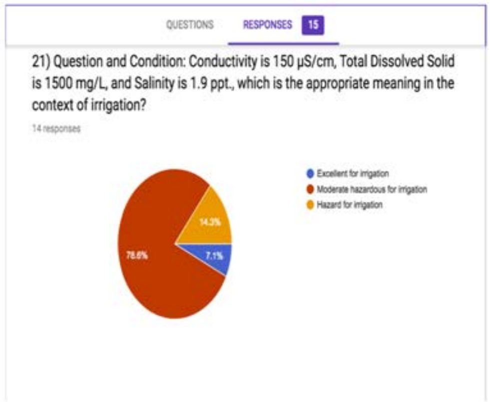

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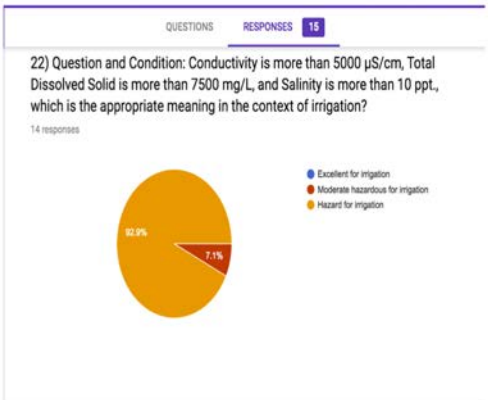

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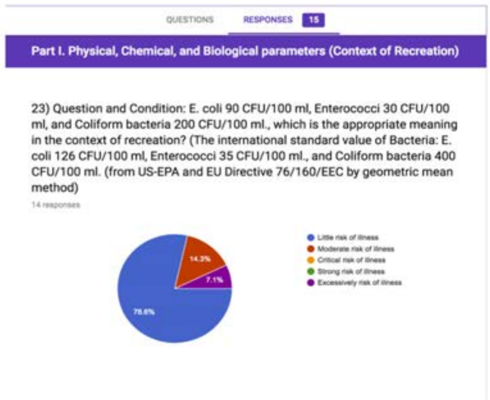

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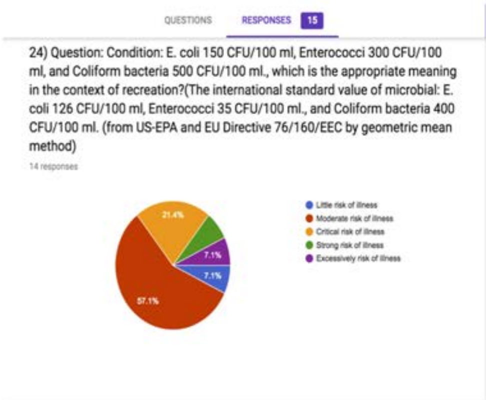
Fig. B.6 Part I. Physical, Chemical, and Biological parameters in Context of Irrigation



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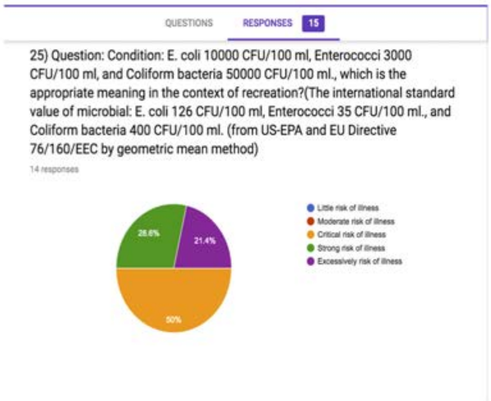

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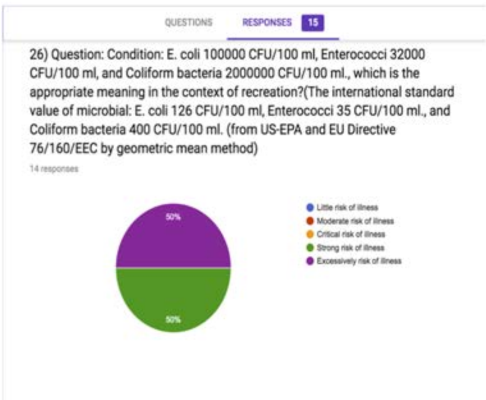

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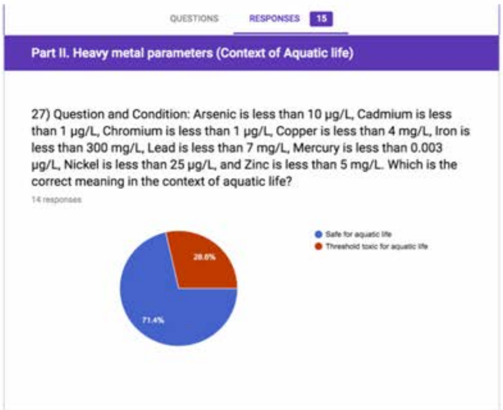
Fig. B.7 Part I. Physical, Chemical, and Biological parameters in Context of Recreation



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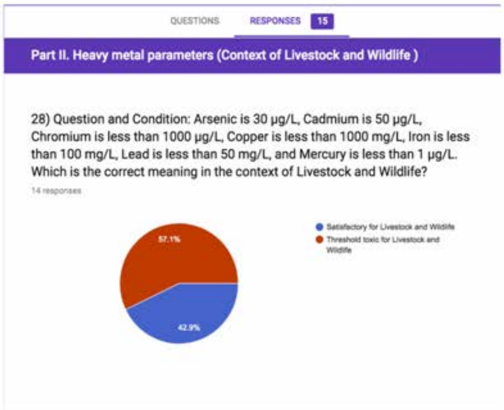

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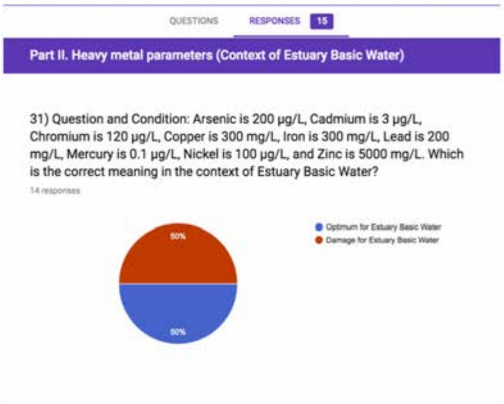

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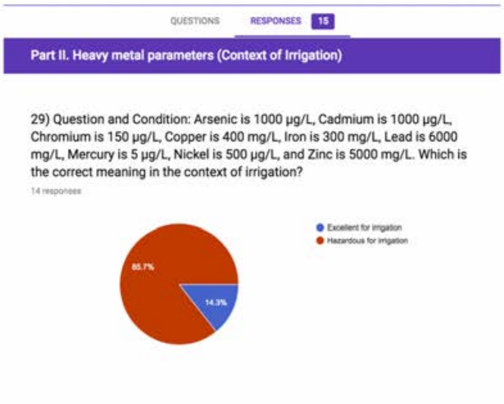

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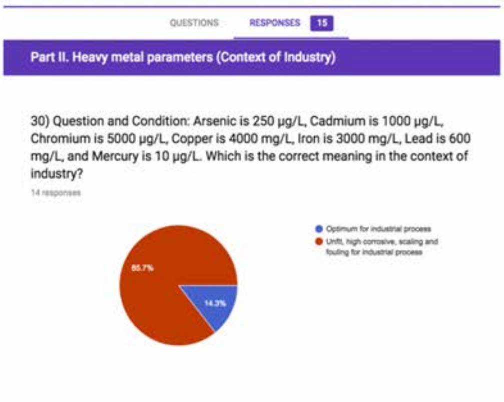

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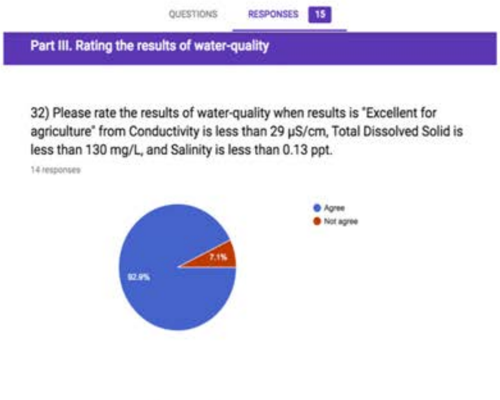
Fig. B.8 Part II. Heavy metal parameter



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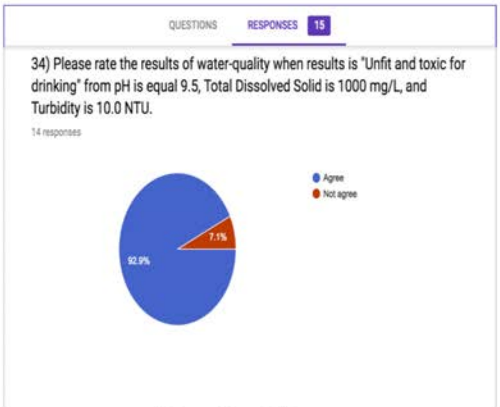

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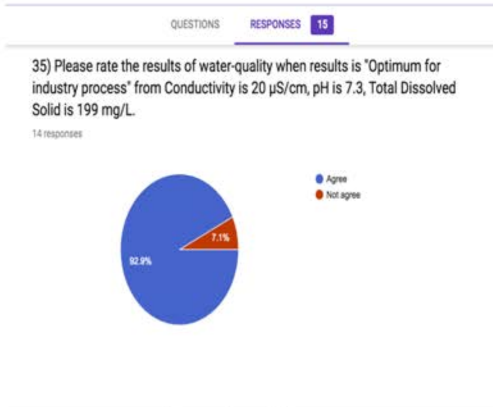

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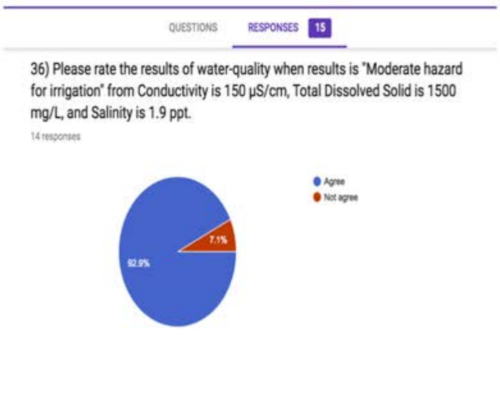
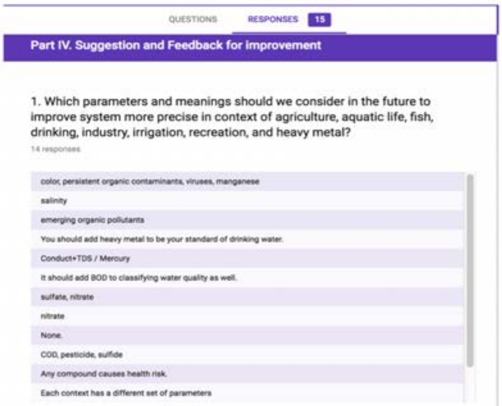


(Question 36)

Fig. B.9 Part III. Rating the results of water-quality



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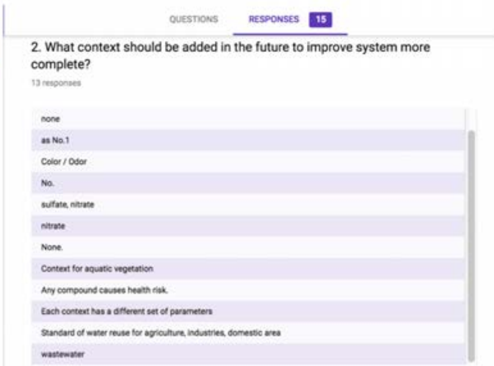

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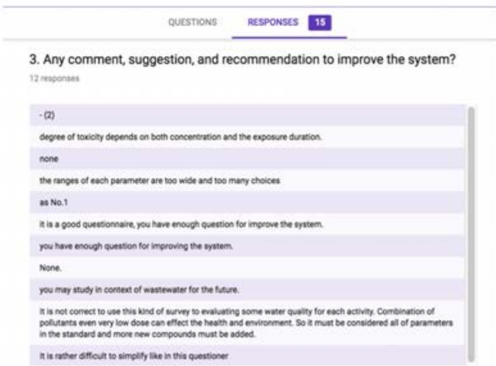

(Question 39)

Fig. B.10 Part IV. Suggestion and Feedback

Appendix C

Research Publication

Research presentation

- Veesommai C. and Kiyoki Y. 2015. River Water-quality Analysis: Critical Contaminate Detection, Classification of Multiple- water-quality-parameters Values and Real-time Notification by rSPA Processes. 2015 International Electronics Symposium (IES) co-sponsored IEEE, vol. 17 (2015), p. 212-217. (Best paper Award).

Journal Publication

- Veesommai C., Kiyoki Y., Sasaki S. and Chawakitchareon P. 2016. Wide-Area River-Water Quality Analysis and Visualization with 5D World Map System. Information Modelling and Knowledge Base XXVII, Vol. 280. p. 31-43.

- Veesommai C. and Kiyoki Y. 2016. The rSPA Processes of River Water-quality Analysis System for Critical Contaminate Detection, Classification Multiple- water-quality-parameter Values and Real-time Notification. EMITTER International Journal of Engineering Technology, Vol. 4 (1), July, p 31-45. (ISSN: 2443-1168).

- Veesommai C., Kiyoki Y., Sillberg P., Soini J., Jaakkol H. and Chawakitchareon P. 2016. The rSPA Process Realization: The Creation of River Heavy Metal Evaluation Index (rHMEI) by Using Dimensional Subspace of Heavy Metal. 2016 International Transaction Journal of Engineering Management, Applied Science and Technologies, Vol 7 (3), 189 - 203. (ISSN 2228-9860, eISSN 1906-9642).

- Veesommai C., Kiyoki Y. and Sasaki S. 2017. A Multi-dimensional River-water Quality Analysis System for interpreting Environmental Situations. Information Modelling and Knowledge Base XXVIII, Vol. 281. p. 31-43.
- Veesommai C. and Kiyoki Y. Spatial Dynamics of The Global Water Quality Analysis System with Semantic-ordering functions. Information Modelling and Knowledge Base XXIX, Vol. 282. January 2018, 12 pages. (to appear)